Ch: 1,2

Passive elements

	R	L	C
Voltage (v)	Ri	$L\frac{di}{dt}$	$\frac{1}{C}\int_{t_0}^{T} i\,dt + v(t_0)$
Current (i)	$\frac{V}{R}$	$\frac{1}{L}\int_{t_0}^{T} v\,dt + i(t_0)$	$C\frac{dv}{dt}$
Power, $P = vi$	i^2R , $\frac{V^2}{R}$	$Li\frac{di}{dt}$	$CV\frac{dv}{dt}$

"حب إسعاد الناس يجعلك تبدع وتفعل ما لم تكن تتوقع فعله" (محمد فتحي)

~~energy stored~~

energy stored	0	$\frac{1}{2}Li^2$	$\frac{1}{2}CV^2$
Ac conbition	$V = IR$	$V_L = IX_L = I\omega L$	$V_C = IX_C = \frac{I}{\omega C}$

ملاحظات

* تأثير C / L يظهر في الفترة الانتقالية سواء في DC أو AC إما هذا يظهر في AC طبيعي.
* المقاومة لا تختزن الطاقة وإنما تبددها.
* الملف يختزن الطاقة في شكل مغناطيسي.
* المكثف يختزن الطاقة في شكل كهربي.

* An Inductor doesnot Permit as instantaneous change in it's terminal current. الملف لا يسمح بتغير لحظى في التيار

* An capacitor doesnot permit an instantaneous change in its terminal voltage.

* An Resistance Permit an instantaneous change in its terminal voltage and current.

At steady state

* Inductor apears as ashort circuit in relation to constant terminal current.

* Capacitor apears as open circuit in relation to constant terminal voltage.

Active elements

- Independent current source. مصدر يعطى تيار مهما حدث

- Dependent current source. يعطى تيار قيمته تعتمد على تيار آخر في الدائرة.

Types of circuits (1) first order

* RL - RC circuits [(natural - step) response] يتم دراستهم

(2) second order

RLC circuits

Response الإستجابة الناتجة عن تغيرما

① natural response.

* الدائرة الكهربية بها مصدر (active) وتعمل استجابة لتغير ما تحت تأثير الطاقة المختزنة.

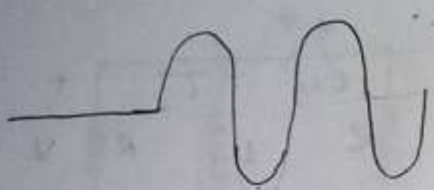
② step response.

* تعرضت الدائرة الكهربية لتغير ما بعد أن كان ثابتاً.

③ Ac response.

* لو المصدر كان (Ac) بعد أن كان المصدر = صفر.

ومش شرط ان الموجة تكون (sinwave) فقط



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* Any differential equation has four elements:-

① Independent variable. متغير مستقل (الذي يتم عليه التفاضل)

$(t) \leftarrow \frac{di}{dt}$

② Dependent variable

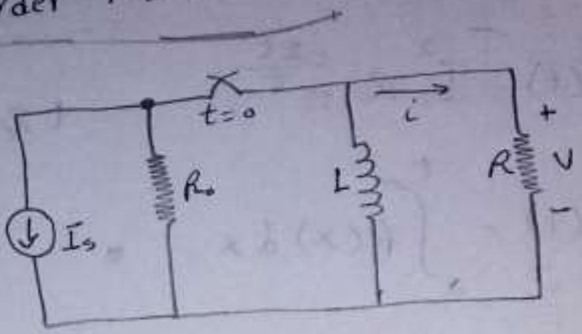
③ Parameters or coefficients. معلومات المتغير التابع وتفاضلاته

④ forcing function or disturbance.

0^- ← اللحظة التي تسبق تغير حالة الـ switch مباشرة.

0^+ ← اللحظة التي تلي تغير حالة الـ switch مباشرة.

Natural Response of First Order RL circuit

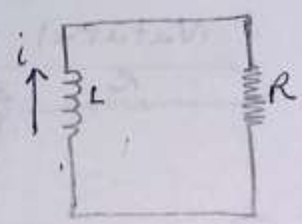


* قبل فتح المفتاح كانت الدائرة مستقرة فكان التيار I_s يمر بأكمله في الملف فتكون الطاقة المختزنة $(\frac{1}{2} L i^2)$

at : $t < 0$

$$I_o = I_s$$

at : $t \geq 0$



$$L \frac{di}{dt} + iR = 0$$

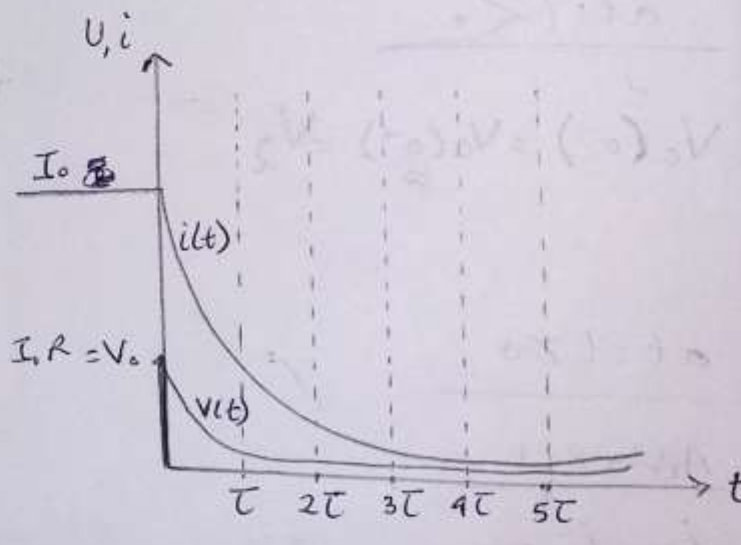
$$\frac{di}{dt} = \frac{-iR}{L}$$

$$\int_{I_o}^{i(t)} \frac{di}{i} = \int_0^t \frac{-R}{L} dt$$

$$\ln i(t) - \ln I_o = \frac{-R}{L} t$$

$$\frac{i(t)}{I_o} = e^{\frac{-R}{L} t}$$

$$\boxed{i(t) = I_o e^{\frac{-t}{\tau}} \qquad t \geq 0}$$



$$\tau = \frac{L}{R}$$

$$\boxed{v(t) = I_o R e^{-t/\tau} \qquad t \geq 0^+}$$

$$P = vi$$

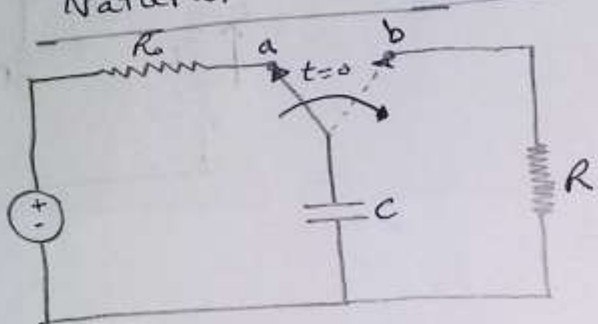
$$P(t) = I_0^2 R e^{\frac{-2t}{\tau}} \qquad t \geq 0^+$$

$$w(t) = \int_0^t P(x)\,dx$$

$$w(t) = \frac{\tau}{2} I_0^2 R \left(1 - e^{-2t/\tau}\right)$$

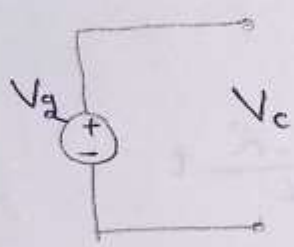
$$w(\infty) = \frac{\tau}{2} I_0^2 R = \frac{1}{2} L I_0^2$$

Natural response of RC circuit



at: t < 0

$$V_c(0^-) = V_c(0^+) = V_g$$

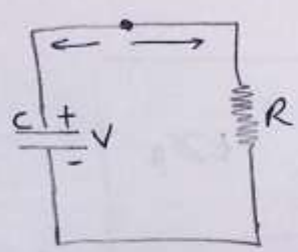


at: t ≥ 0

Apply KCL

$$i_R + i_C = 0$$

$$C\frac{dv}{dt} + \frac{V}{R} = 0$$



$$\frac{dv}{dt} = \frac{-V}{RC}$$

$$\therefore \int_{V_c(0)}^{V(t)} \frac{dv}{V} = \int_0^t \frac{-1}{RC}\,dt$$

$$\ln V(t) - \ln V_c(0) = \frac{-t}{RC}$$

$$\frac{V(t)}{V_c(0)} = e^{-t/\tau} \qquad \boxed{\tau = RC}$$

$$\boxed{V(t) = V_c(0)\, e^{-t/\tau} \qquad t \geq 0}$$

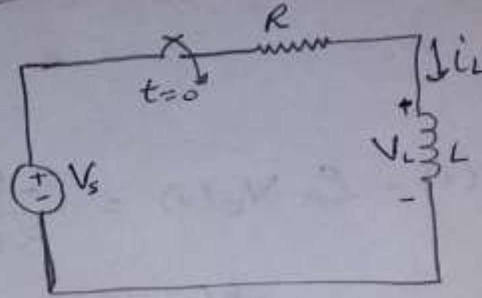
$$i(t) = \frac{V_c(t)}{R} = \frac{V_c(0)}{R} e^{-t/\tau}$$

$$P(t) = i^2(t) R = \frac{V_c(0)^2}{R} e^{-2t/\tau}$$

$$w(t) = \int_0^t P(t)\,dt$$

$$\boxed{w(t) = \frac{1}{2} C V_0^2 \left(1 - e^{-2t/\tau}\right)}$$

step response of an RL circuit



At t<0

$i_L(0) = I_0$

at t ≥ 0

Apply KVL

$$V_s = iR + L\frac{di}{dt}$$

$$\frac{di}{dt} = \frac{V_s - iR}{L} = \frac{-R}{L}\left(i - \frac{V_s}{R}\right)$$

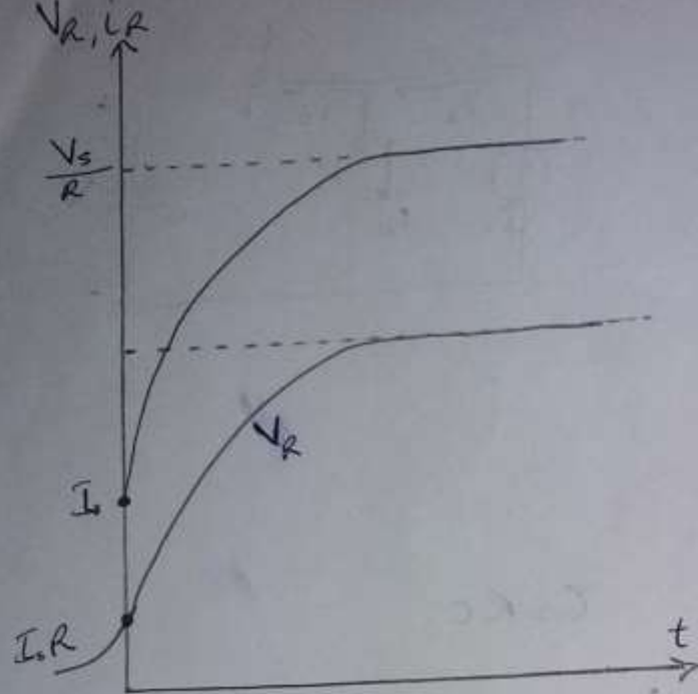
$$\int_{I_0}^{i(t)} \frac{di}{i - \frac{V_s}{R}} = \int_0^t \frac{-R}{L}\, dt$$

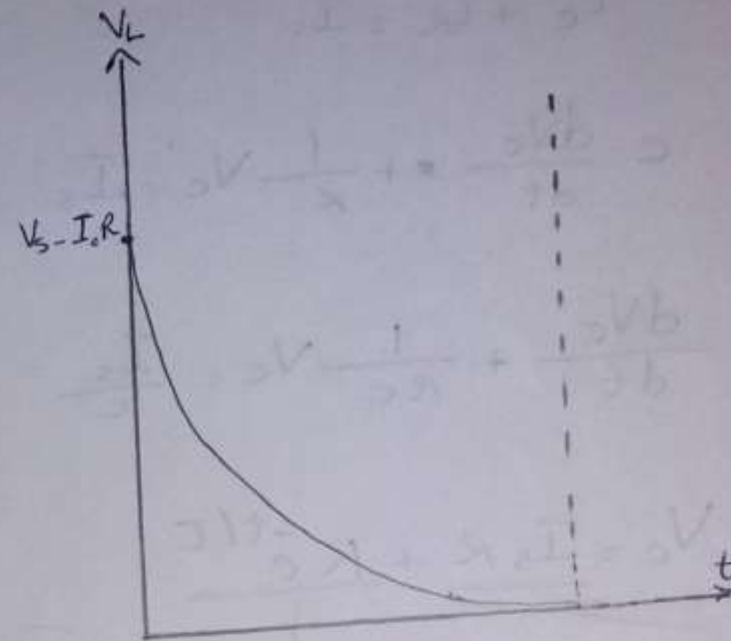
$$\boxed{i(t) = \frac{V_s}{R} + \left(I_0 + \frac{V_s}{R}\right) e^{-t/\tau}} \qquad \tau = \frac{L}{R}$$

$$\text{if } I_0 = 0 \Rightarrow i(t) = \frac{V_s}{R}\left(1 - e^{-t/\tau}\right)$$

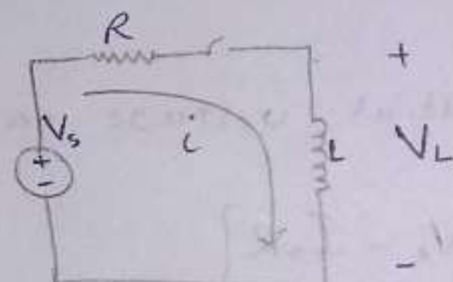
$$V_L = L\frac{di}{dt} = \left(V_s - I_0 R\right) e^{-t/\tau}$$

$$V_R = V_s + \left(I_0 R - V_s\right) e^{-t/\tau}.$$





Another case



$$i = \frac{V_s - V_L}{R}$$

$$\frac{di}{dt} = \frac{-1}{R}\frac{dV_L}{dt}$$

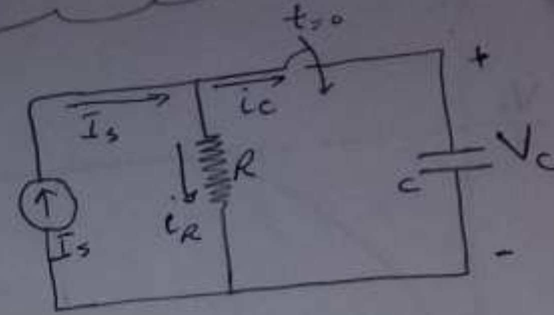
$$L\frac{di}{dt} = \frac{-L}{R}\frac{dV_L}{dt}$$

$$V_L = \frac{-L}{R}\frac{dV_L}{dt}$$

$$V_L(0) = V_s - I_0 R$$

$$\boxed{\therefore V_L = K' e^{-t/\tau}}$$

step Response of an RC circuit



$$i_c + i_R = I_s$$

$$c\frac{dV_c}{dt} + \frac{1}{R}V_c = I_s$$

$$\frac{dV_c}{dt} + \frac{1}{RC}V_c = \frac{I_s}{c}$$

$$V_c = \underbrace{I_s R}_{\text{(steady state)}} + \underbrace{K e^{-t/\tau}}_{\text{(transient)}} \qquad \tau = RC$$

*using initial voltage on capacitor (V_0) [is considered]

$$K = [V_0 - I_s R]$$

$$\boxed{V_c = I_s R + (V_0 - I_s R)e^{-t/\tau}} \qquad t \geq 0 \longrightarrow *$$

For zero I.C (Initial condition)

$$V_c = I_s R(1 - e^{-t/\tau})$$

$$i_c = c\frac{dV_c}{dt} \quad \text{(general case)}$$

$$\boxed{i_c = \left(I_s - \frac{V_0}{R}\right)e^{-t/c}} \qquad t \geq 0^+$$

$\therefore V_c = i_R R = (I_s - i_c) R$

$$\frac{dV_c}{dt} = -R \frac{di_c}{dt} \qquad * C$$

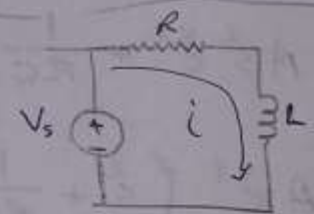
$$C \frac{dV_c}{dt} = -RC \frac{di_c}{dt}$$

$$i_c = -RC \frac{di_c}{dt}$$

$$\boxed{\frac{di_c}{dt} + \frac{1}{RC} i_c = 0}$$

from * we can get general form.

$$\boxed{A(t) = A(\infty) + \left[A(0^+) - A(\infty)\right] e^{-t/\tau}}$$

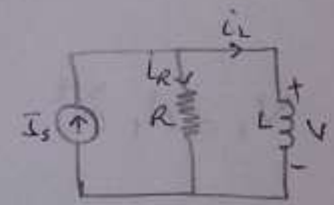


General solution

$$\frac{dx}{dt} + \frac{1}{\tau} x = K \qquad x(t = t_0) = X_0$$

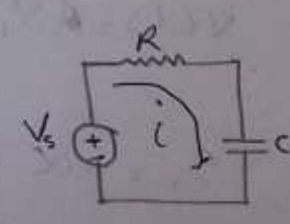
x ـــ قد تكون جهد أو تيار

$$x = x_{ss} + x_t$$



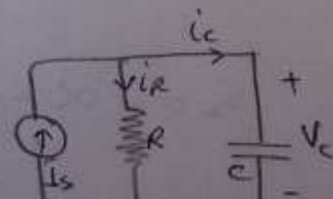
$$x_{ss}: \frac{dx}{dt} = 0 \Rightarrow x_{ss} = K\tau$$

$$x_t = A e^{-(t-t_0)/\tau} = K\tau + A e^{-(t-t_0)/\tau}$$



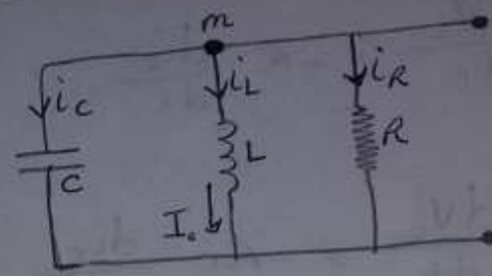
$$\boxed{\therefore x(t) = X_f + (X_0 - X_f) e^{-(t-t_0)/\tau}}$$

تصلح للأربع
معادلات السابقة



we need :

Natural response of Parallel RLC



at m

$$i_R + i_L + i_C + I_0 = 0$$

$$\frac{V}{R} + \frac{1}{L}\int v\,dt + C\frac{dv}{dt} + I_0 = 0$$

بإجراء التفاضل بالنسبة ل t

$V(0) = V_0 , \quad i_L(0) = I_0$

$$\frac{1}{R}\frac{dv}{dt} + \frac{v}{L} + C\frac{d^2v}{dt} = 0$$

$$\boxed{\frac{d^2v}{dt^2} + \frac{1}{RC}\frac{dv}{dt} + \frac{1}{LC}V = 0}$$

$V = Ae^{st} \quad , \frac{dv}{dt} = Ase^{st} \quad , \frac{d^2v}{dt^2} = As^2e^{st}$

$$As^2e^{st} + \frac{1}{RC}Ase^{st} + \frac{1}{LC}Ae^{st} = 0$$

$$Ae^{st}\left(s^2 + \frac{1}{RC}s + \frac{1}{LC}\right) = 0$$

$V_1 = A_1e^{s_1t}$, ~~and~~ $V_2 = A_2e^{s_2t}$

$$V(t) = \cancel{A}V_1 + V_2 = A_1e^{s_1t} + A_2e^{s_2t}$$

$$S_1 = -\alpha + \sqrt{\alpha^2 - \omega_0^2}$$

$$S_2 = -\alpha - \sqrt{\alpha^2 - \omega_0^2}$$

where:

$\alpha = \frac{1}{2RC} \longrightarrow$ referense frequency

rad/sec

$\omega_0 = \frac{1}{\sqrt{LC}} \longrightarrow$ resonance frequency

① $\alpha > \omega_0 \longrightarrow$ "over damped"

(S_1, S_2 real and distinct)

$v(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t}$

② $\alpha < \omega_0 \longrightarrow$ "under damped"

(S_1, S_2 complex and conjugated)

$$v(t) = e^{-\alpha t}\left(B_1 \cos(\omega_d t) + B_2 \sin(\omega_d t)\right)$$

where: $\omega_d = \sqrt{\omega_0^2 - \alpha^2} \longrightarrow$ damped radian frequency

③ $\alpha = \omega_0 \longrightarrow$ "critically damped"

(S_1, S_2 real and equal)

$$v(t) = D_1 t e^{-\alpha t} + D_2 e^{-\alpha t}$$

① over damped response (prof) $(\alpha > \omega_0)$

$$V(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t}$$

$A_1, A_2 \longrightarrow$ initial condition , $V_0(0^+) \rightarrow$ initial voltage of capacitor.

$$\frac{dv}{dt}(0^+) = \frac{i_c(0^+)}{c} = \frac{-i_L(0^+) - i_R(0^+)}{c} = \frac{-i_L(0^+) - \frac{V(0^+)}{R}}{c}$$

$$\frac{dv}{dt}(0^+) = A_1 s_1 + A_2 s_2$$

$$V(0^+) = A_1 + A_2$$

② critically damped

$$\alpha = \omega_0$$

$$s_1 = s_2 = -\alpha = \frac{-1}{2RC}$$

$$V(t) = D_1 t e^{-\alpha t} + D_2 e^{-\alpha t}$$

$$\boxed{V(0^+) = D_2}$$

$$\boxed{\frac{dv}{dt}(0^+) = D_1 - \alpha D_2}$$

③ under damped $(\alpha < \omega_0)$

$$S_{1,2} = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$$

$$= -\alpha \pm J\sqrt{\omega_0^2 - \alpha^2} = -\alpha \pm J\omega_d$$

where: $\omega_d = \sqrt{\omega_0^2 - \alpha^2} \longrightarrow$ damped radian frequency

$$v(t) = A_1 e^{S_1 t} + A_2 e^{S_2 t} = A_1 e^{(-\alpha + J\omega_d)t} + A_2 e^{(-\alpha - J\omega_d)t}$$

$$= A_1 e^{-\alpha t} e^{J\omega_d t} + A_2 e^{-\alpha t} e^{-J\omega_d t}$$

$$e^{\pm J\theta} = \cos\theta \pm \sin\theta$$

$$v(t) = A_1 e^{-\alpha t}\left(\cos(\omega_d t) + \sin(\omega_d t)\right) + A_2 e^{-\alpha t}\left(\cos(\omega_d t) - \sin(\omega_d t)\right)$$

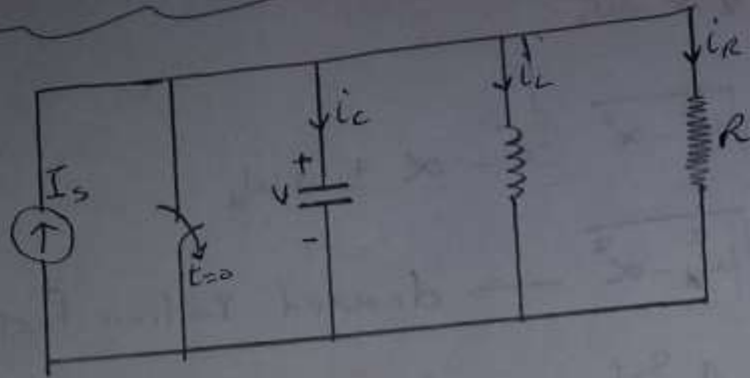
$$v(t) = e^{-\alpha t}\left[\underbrace{(A_1 + A_2)}_{B_1}\cos(\omega_d t) + \underbrace{J(A_1 - A_2)}_{B_2}\sin(\omega_d t)\right]$$

$$\boxed{v(t) = e^{-\alpha t}\left[B_1 \cos(\omega_d t) + B_2 \sin(\omega_d t)\right]}$$

$$v(0^+) = B_1$$

$$\frac{dv}{dt}(0^+) = -\alpha B_1 + \omega_d B_2$$

step response of Parallel RLC



At $t \geq 0$

Apply KCL

$$I_s = i_C + i_R + i_L$$

$$I_s = C\frac{dv}{dt} + \frac{v}{R} + \frac{1}{L}\int v\,dt + I_0$$

* بإجراء الاشتقاق
بالنسبة لـ t

$$0 = \frac{C\,d^2v}{dt^2} + \frac{v}{L} + \frac{1}{R}\frac{dv}{dt} = 0$$

$$\boxed{\frac{d^2v}{dt^2} + \frac{1}{LC}v + \frac{1}{RC}\frac{dv}{dt} = 0}$$

$$v = A e^{st}, \quad \frac{dv}{dt} = A s e^{st}, \quad \frac{d^2v}{dt^2} = A s^2 e^{st}$$

$$A e^{st}\left(s^2 + \frac{1}{RC}s + \frac{1}{LC}\right) = 0$$

$$s_{1,2} = \frac{-1}{2RC} \pm \sqrt{\left(\frac{1}{2RC}\right)^2 - \frac{1}{LC}}$$

$$= -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$$

① $\alpha > \omega_0$ ⟶ over damped ⇒ $v(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t}$

② $\alpha < \omega_0$ ⟶ under damped ⇒ $v(t) = e^{-\alpha t}(B_1 \cos \omega_d t + B_2 \sin \omega_d t)$

③ $\alpha = \omega_0$ ⟶ critically ⇒ $v(t) = D_1 t e^{-\alpha t} + D_2 e^{-\alpha t}$

$$i_L(t) = I_s + \begin{cases} A_1 e^{s_1 t} + A_2 e^{s_2 t} \longrightarrow \text{over damped} \\ (B_1 \cos(\omega_d t) + B_2 \sin(\omega_d t)) e^{-\alpha t} \longrightarrow \text{under damped} \\ D_1 t e^{-\alpha t} + D_2 e^{-\alpha t} \longrightarrow \text{critically damped} \end{cases}$$

$$i_R(t) = \frac{v(t)}{R} = \underbrace{\frac{A_1}{R}}_{A_1'} e^{s_1 t} + \underbrace{\frac{A_2}{R}}_{A_2'} e^{s_2 t} + 0$$

General form

$$A(t) = A(\infty) + \begin{cases} A_1 e^{s_1 t} + A_2 e^{s_2 t} \\ e^{-\alpha t}(B_1 \cos \omega_d t + B_2 \sin \omega_d t) \\ D_1 t e^{-\alpha t} + D_2 e^{-\alpha t} \end{cases}$$

$$i_L(t) = I_f + A_1 e^{s_1 t} + A_2 e^{s_2 t}$$

$$i_L(0^+) = i_f + A_1 + A_2$$

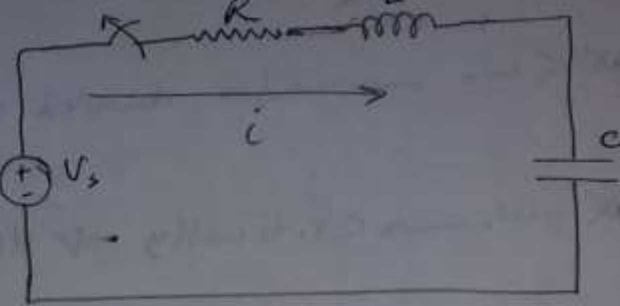
$$\frac{di_L(0^+)}{dt} = \frac{V_L(0^+)}{L} = A_1 s_1 + A_2 s_2$$

$i_L(\infty) = I_f$

$V_C(\infty) = 0$

$$i_L = \frac{1}{L}\int_0^t v(t)\,dt + I_0$$

Natural ~~and step~~ resopce of series RLC circuits



At $t > 0$

$V_R + V_L + V_C = 0$

$$iR + L\frac{di}{dt} + \frac{1}{C}\int_0^t i\,dt + V_0 = 0$$

$$\frac{L\,d^2 i}{dt^2} + \frac{i}{C} + \frac{R\,di}{dt} = 0$$

$$\boxed{\frac{d^2 i}{dt^2} + \frac{R}{L}\frac{di}{dt} + \frac{1}{LC} i = 0}$$

$$i = A e^{st}, \quad \frac{di}{dt} = A s e^{st}, \quad \frac{d^2 i}{dt^2} = A s^2 e^{st}$$

$$A s^2 e^{st} + \frac{R}{L} A s e^{st} + \frac{1}{LC} A e^{st} = 0$$

$$A e^{st}\left(\underbrace{s^2 + \frac{R}{L}s + \frac{1}{LC}}_{\text{ch/s}}\right) = 0$$

$$s_{1,2} = \frac{-R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$$

$$s_{1,2} = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$$

$\alpha = \frac{R}{2L}$, $\omega_0 = \frac{1}{\sqrt{LC}}$

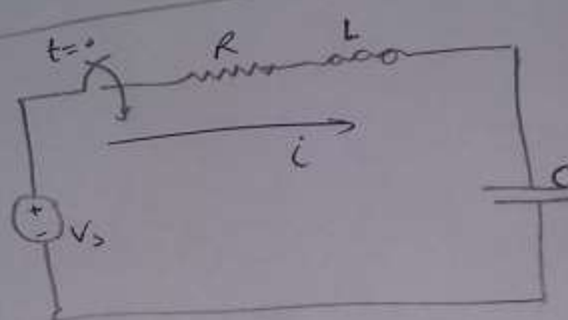
$\alpha > \omega_0 \longrightarrow$ over $\Rightarrow i_n(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t}$

$\alpha < \omega_0 \longrightarrow$ under $\Rightarrow i_n(t) = e^{-\alpha t}(B_1 \cos \omega_d t + B_2 \sin \omega_d t)$

$\alpha = \omega_0 \longrightarrow$ critically $\Rightarrow i(t) = D_1 t e^{-\alpha t} + D_2 e^{-\alpha t}$

$V_L = L\frac{di}{dt}$, $V_C = \frac{1}{C}\int_0^t i\,dt + V_0$, $V_R = iR$

step response of series RLC



$V_s = V_R + V_L + V_C$

$V_s = iR + L\frac{di}{dt} + \frac{1}{C}\int_0^t i\,dt + V_0$

$0 = L\frac{d^2 i}{dt^2} + R\frac{di}{dt} + \frac{i}{C} = 0$

$$\boxed{\frac{d^2 i}{dt^2} + \frac{R}{L}\frac{di}{dt} + \frac{1}{LC}\, i = 0}$$

وبعد ذلك نمشي بنفس خطوات
ال Natural

$$A(t) = A_f + \begin{cases} A_1 e^{s_1 t} + A_2 e^{s_2 t} \\ B_1 e^{-\alpha t}\cos \omega_d t + B_2 e^{-\alpha t}\sin \omega_d t \\ D_1 t e^{-\alpha t} + D_2 e^{-\alpha t} \end{cases}$$

Ch : 3

3-phase

Ch: 3

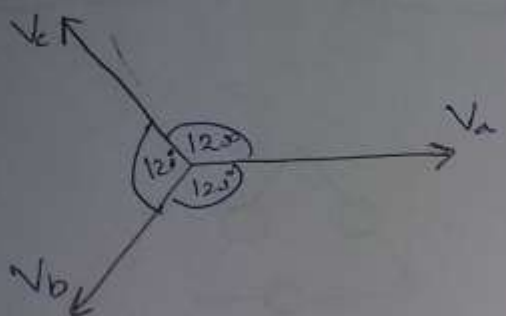
Three Phase circuits

- Balanced three phase Voltages

* عبارة عن ثلاثة جهود ليهم نفس ال magnitute وبينهم phase shift 120°

⇒ +ve sequence (abc)

V_a عن:
- متأخر ب 120° V_b
- متقدم ب 120° V_c



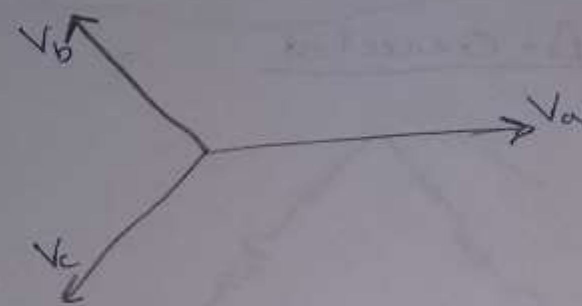
$$V_a = |V_\phi| \angle 0$$

$$V_b = |V_\phi| \angle -120^\circ$$

$$V_c = |V_\phi| \angle 120^\circ$$

⇒ -ve sequence (acb)

V_a عن:
- متقدم ب 120° V_b
- متأخر ب 120° V_c



$$V_a = |V_\phi| \angle 0$$

$$V_b = |V_\phi| \angle 120^\circ$$

$$V_c = |V_\phi| \angle -120^\circ$$

شرط ال Balanced

① نفس ال magnitude -

② بينهم phase shift 120° .

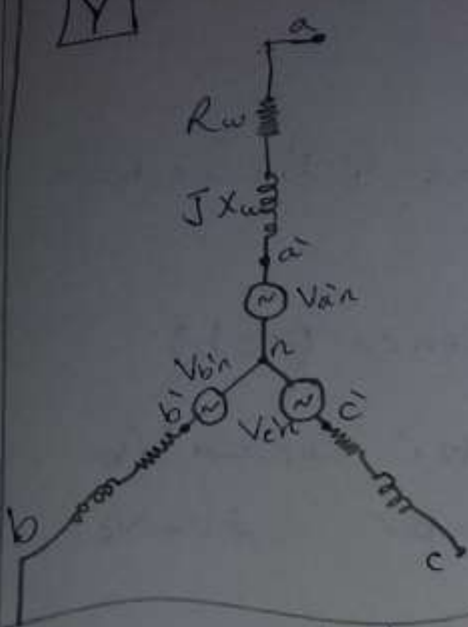
③ $V_a + V_b + V_c = 0$

* 3 ϕ - voltage source

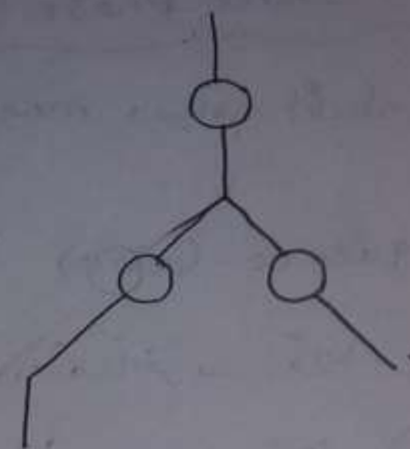
[1] Y - Connected.

[2] Δ - Connected.

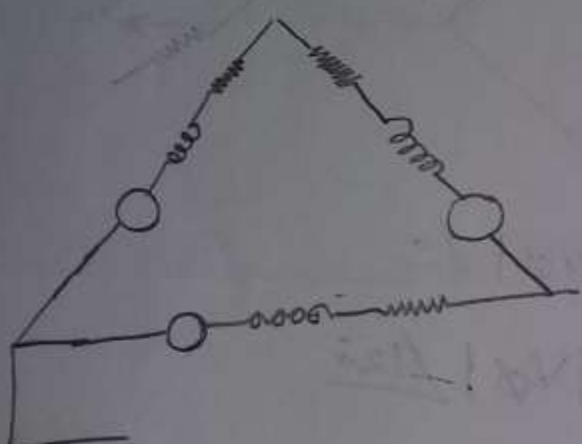
Y



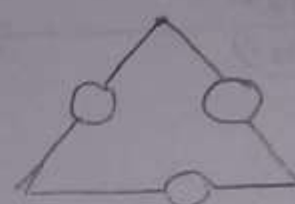
ideal $\longrightarrow$



2 Δ - Connected



ideal $\longrightarrow$



*** They are:**

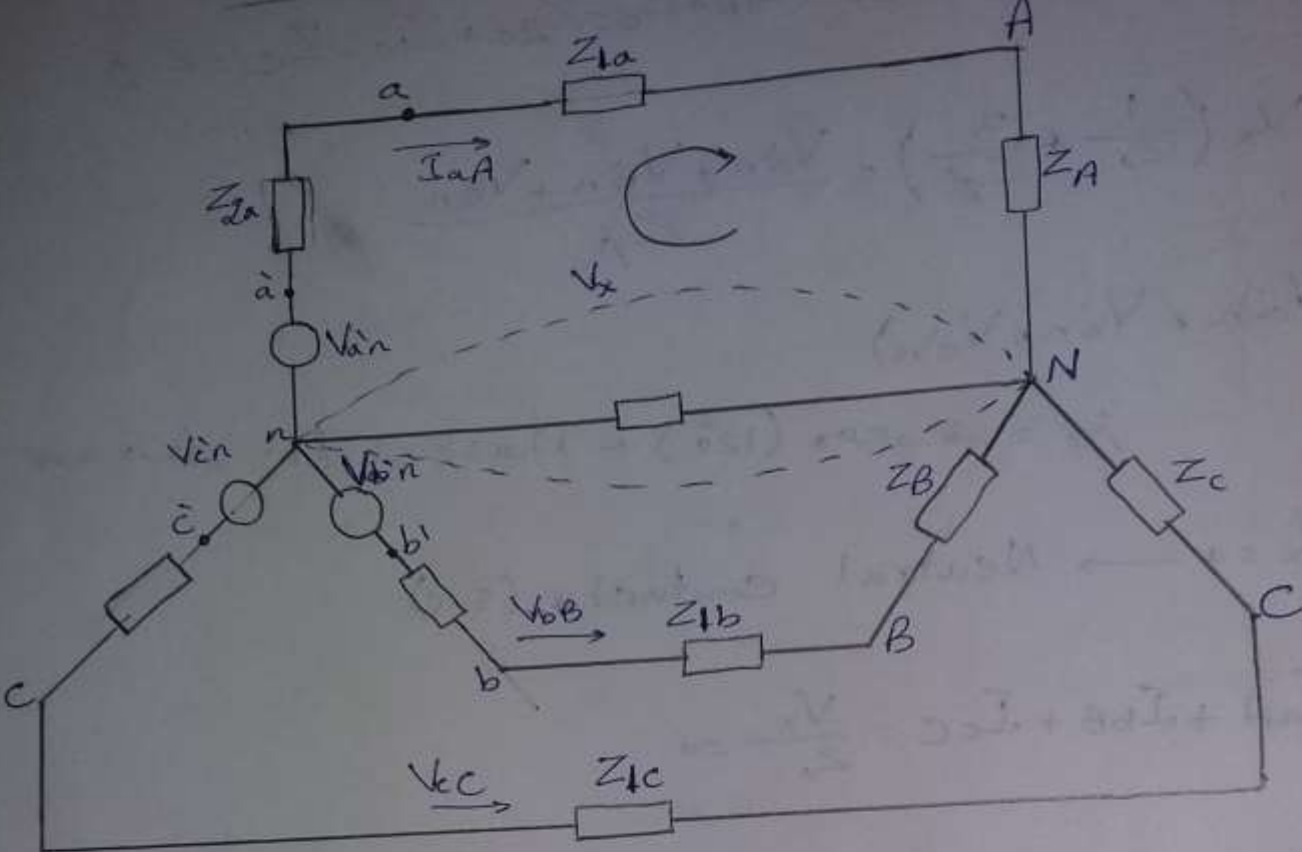
① Y - Y (source → Y, load → Y)

② Y - Δ

③ Δ - Y

④ Δ - Δ

▢ Y - Y Connected



$$I_o = I_{aA} + I_{bB} + I_{cC}$$

$$= \frac{V_{a'n} - V_x}{Z_{ga} + Z_{la} + Z_A} + \frac{V_{b'n} - V_x}{Z_{gb} + Z_{lb} + Z_B} + \frac{V_{c'n} - V_x}{Z_{gc} + Z_{lc} + Z_C}$$

For balanced system:

$$V_a = V_b = V_c = 0$$

$$Z_{ga} = Z_{gb} = Z_{gc}$$

$$Z_A = Z_B = Z_C$$

$$Z_{la} = Z_{lb} = Z_{lc}$$

$$Z_{2a} + Z_{1a} + Z_A = Z_{2b} + Z_{1b} + Z_B = Z_{2c} + Z_{1c} + Z_C = Z_\phi$$

$$V_x \left(\frac{1}{Z_0} + \frac{3}{Z_\phi} \right) = \frac{V_{a'n} + V_{b'n} + V_{c'n}}{Z_\phi}$$

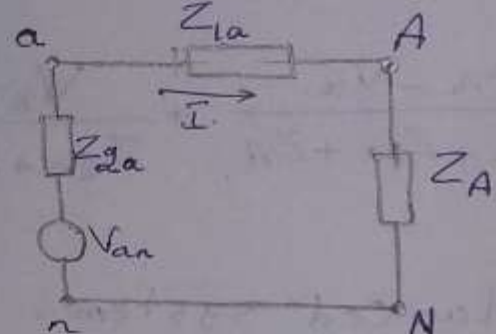
ثلاثة جهود بينهم $(V_{a'n}, V_{b'n}, V_{c'n})$ Phase shift $\leftarrow$ (120°) ومجموعهم = صفر

$V_x = 0 \longrightarrow$ Neutral conductor (s.c)

$$I_{aA} + I_{bB} + I_{cC} = \frac{V_x}{Z_0} = 0$$

$\therefore$ Currents are also Palanced.

if $\rightarrow$ +ve sequence



$V_{AN} = 2\angle 15$

$V_{BN} = 2\angle -105$

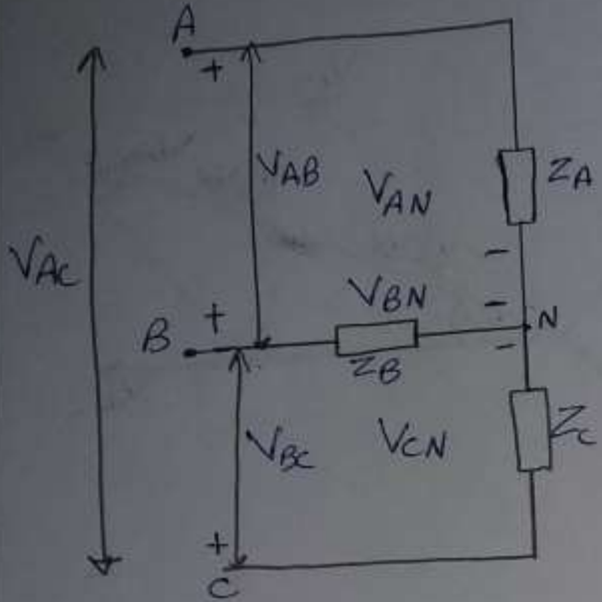
$V_{CN} = 2\angle 135$

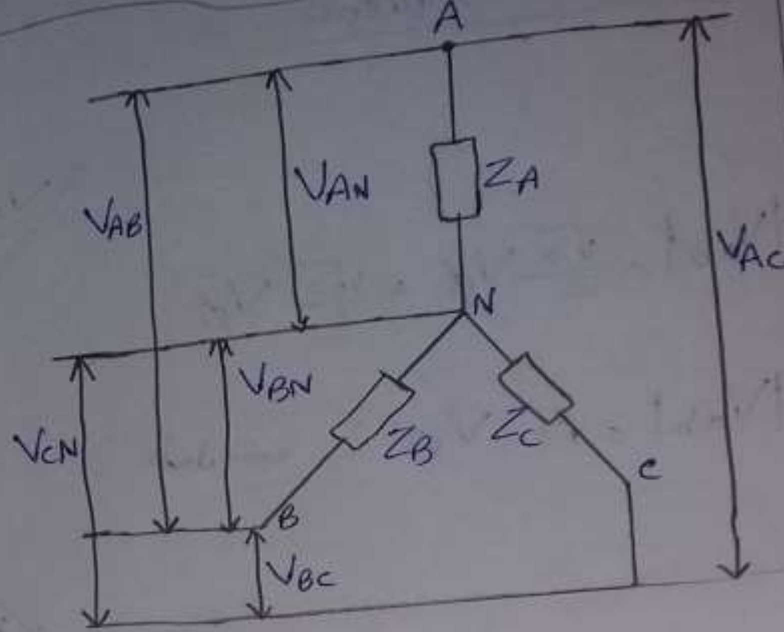
if $\rightarrow$ -ve sequence

$V_{AN} = 2\angle 15$

$V_{BN} = 2\angle 135$

*relationship between Line to Line voltages and phase voltages:





$$V_{AB} - V_{AN} + V_{BN} = 0$$

$$V_{AB} = V_{AN} - V_{BN}$$

$$V_{BC} = V_{BN} - V_{CN}$$

$$V_{CA} = V_{CN} - V_{AN}$$

$$V_{AB} = V_{AN} - V_{BN} = V\phi\angle 0 - V\phi\angle -120$$

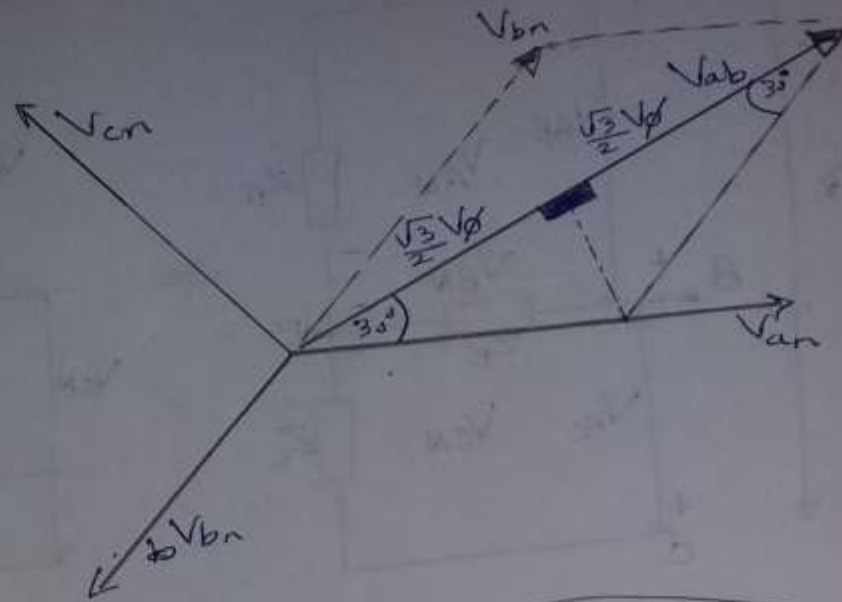
$V_{AB} = \sqrt{3}\, V\phi \angle +30$ → for +ve sequence.

$V_{AB} = \sqrt{3}\, V\phi \angle -30$ → for -ve sequence.

for +ve sequence

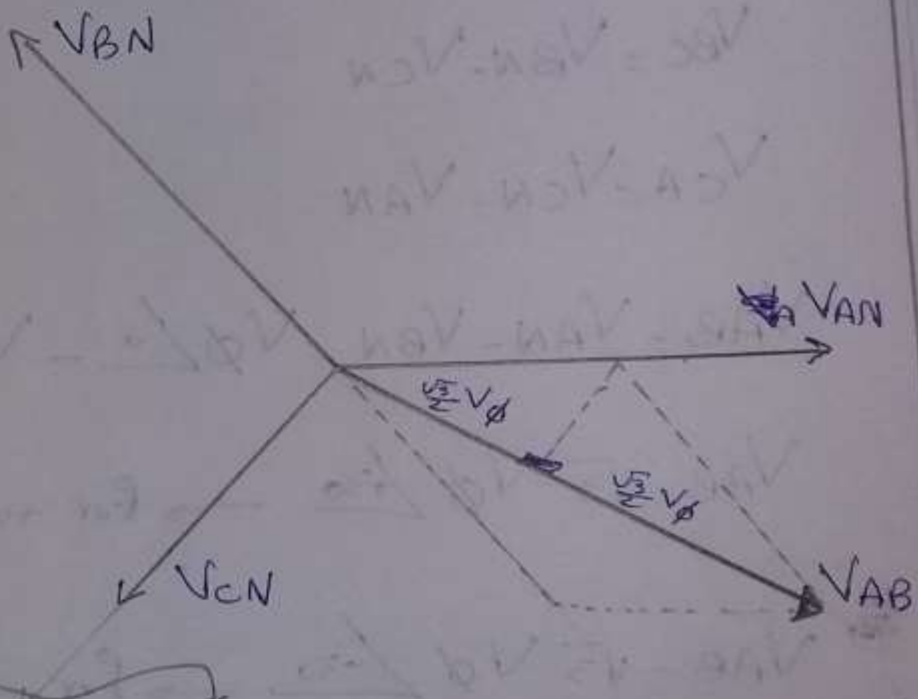
$$|V_{ab}| = \frac{\sqrt{3}}{2} V_\phi + \frac{\sqrt{3}}{2} V_\phi$$

$$|V_{ab}| = \sqrt{3}\, V_\phi$$ طلعتبه



-ve sequence

$$|V_{AB}| = \sqrt{3}\, V_\phi$$

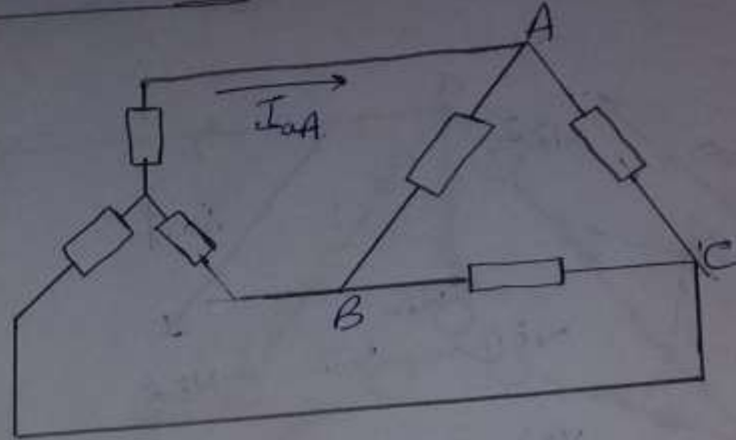


V_{AN}:

$V_{AB} = \sqrt{3}\, V_{AN} \angle{+30} \longrightarrow$ +ve

$V_{AB} = \sqrt{3}\, V_{AN} \angle{-30^\circ} \longrightarrow$ -ve

$\boxed{2}$ Y - Δ Connected

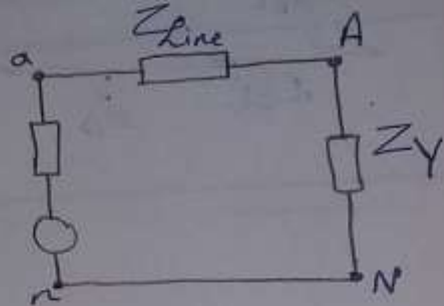


$$Z_Y = \frac{Z_\Delta}{3}$$

$\boxed{\Delta}$

$I_L \neq I_\phi$

$V_L = V_\phi$



$\boxed{Y}$

$I_L = I_\phi$, $V_L \neq V_\phi$

---

* Phase voltage at terminals of load (V_{AB}, V_{BC}, V_{CA})

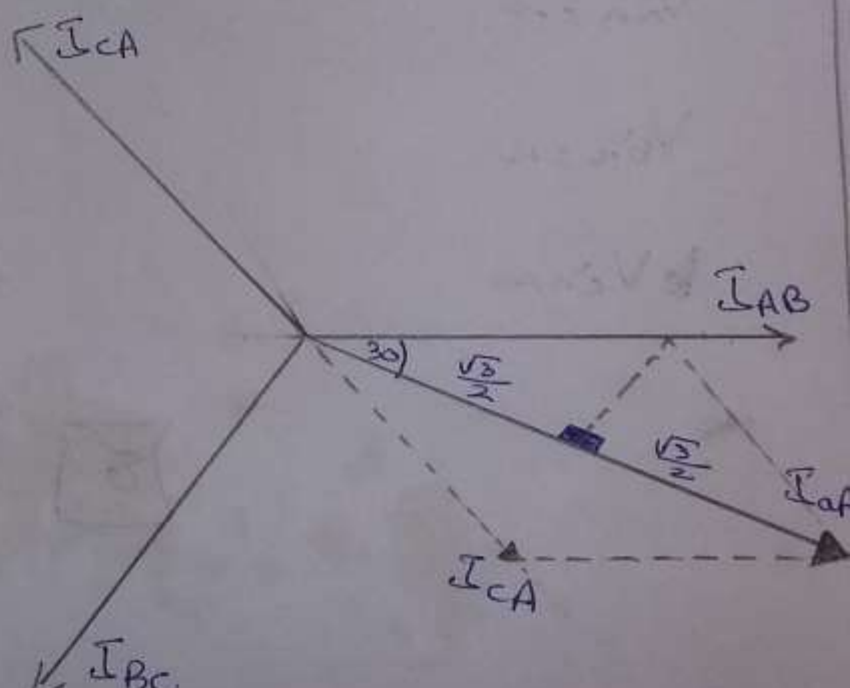
Apply KCL at node A

$I_{aA} = I_{AB} - I_{CA}$

$= I_\phi \angle 0 - I_\phi \angle 120$

$\boxed{I_{aA} = \sqrt{3}\, I_\phi \angle -30}$ → +ve seq.

→ Line current

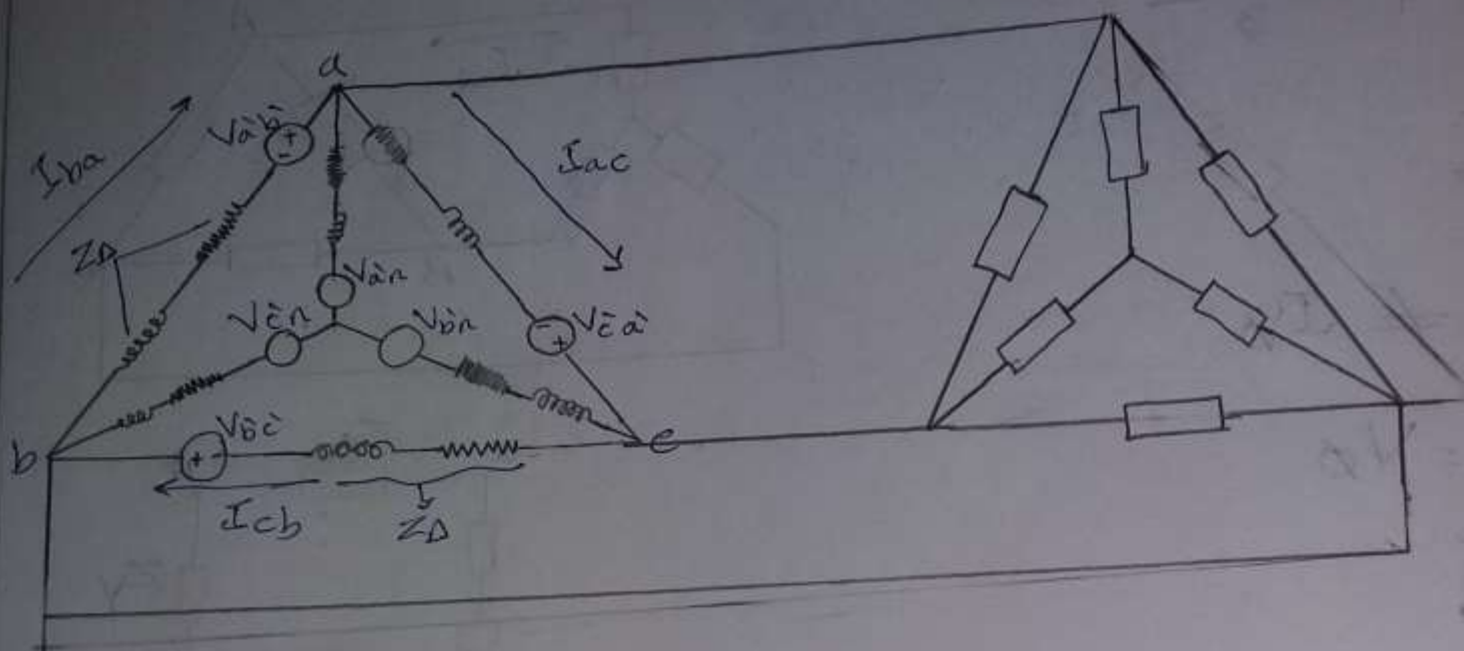


$I_{AB} = I_\phi \angle 0$

$I_{BC} = I_\phi \angle -120$

$I_{CA} = I_\phi \angle 120$

3 Δ/Y Connected



$$Z_Y = \frac{Z_\Delta}{3}$$

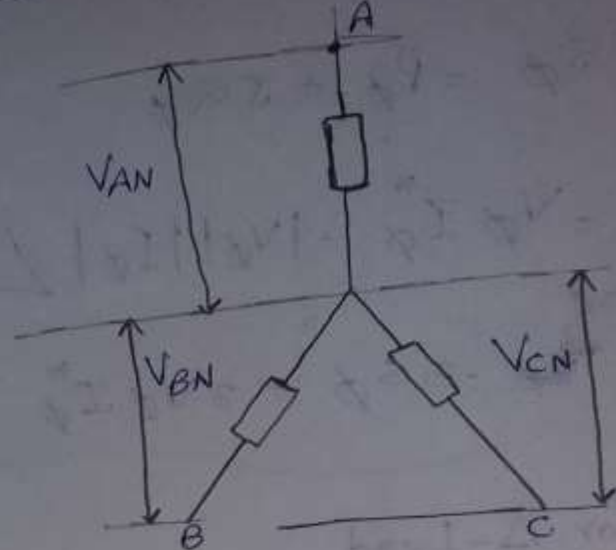
$V_{a'b'} = \sqrt{3}\, V_{a'n} \angle \pm 30$

$V_{a'n} = \sim$

$V_{b'n} = \sim$

$V_{c'n} = \sim$

Power in circuits



For Y-Load

$P_A = |V_{AN}||I_{aA}| \cos(\theta_v - \theta_i)$

$P_B = |V_{BN}||I_{bB}| \cos(\theta_v - \theta_i)$

$P_C = |V_{CN}||I_{cC}| \cos(\theta_v - \theta_i)$

For Balanced system

$|V_{AN}| = |V_{BN}| = |V_{CN}| = V_\phi$

$|I_{aA}| = |I_{bB}| = |I_{cC}| = I_\phi$

$(\theta_v - \theta_i)_A = (\theta_v - \theta_i)_B = (\theta_v - \theta_i)_C = \theta_\phi$

$\therefore P_A = P_B = P_C = V_\phi I_\phi \cos\theta_\phi$

$P_{3\phi} = P_A + P_B + P_C = \boxed{3 V_\phi I_\phi \cos\theta_\phi}$ for Y

$= \sqrt{3}\,\sqrt{3}\,\frac{V_L}{\sqrt{3}} I_L \cos\theta_\phi = \boxed{\sqrt{3} V_L I_L \cos\theta_\phi}$

* Reactive power (Q)

$Q_A = Q_B = Q_C = V_\phi I_\phi \sin\theta_\phi$

$\boxed{Q_{3\phi} = 3 V_\phi I_\phi \sin\theta_\phi = \sqrt{3} V_L I_L \sin\theta_\phi}$ VAR

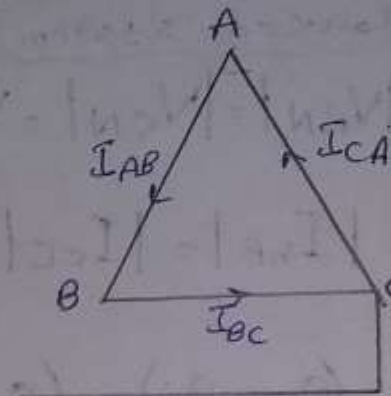
* Apparent Power (s)

$$S_\phi = P_\phi \pm J Q_\phi \quad \begin{array}{l} + \rightarrow \text{Lag} \ (Q_L > Q_C) \\ - \rightarrow \text{Lead} \ (Q_L < Q_C) \end{array}$$

$$= V_\phi I_\phi^* = |V_\phi| |I_\phi| \angle \pm\theta_i \quad VA$$

$$S_{3\phi} = 3 S_\phi = 3 V_\phi I_\phi^*$$

For Δ-Load



$$P_{AB} = |V_{AB}| |I_{AB}| \cos(\theta_v - \theta_i)_{AB}$$

$$P_{BC} = |V_{BC}| |I_{BC}| \cos(\theta_v - \theta_i)_{BC}$$

$$P_{CA} = |V_{CA}| |I_{CA}| \cos(\theta_v - \theta_i)_{CA}$$

$$|V_{AB}| = |V_{BC}| = |V_{CA}| = V_\phi$$

$$|I_{AB}| = |I_{BC}| = |I_{CA}| = I_\phi$$

$$(\theta_v - \theta_i)_{AB} = (\theta_v - \theta_i)_{BC} = (\theta_v - \theta_i)_{CA} = \theta_\phi$$

$$P_{AB} = P_{BC} = P_{CA} = P_\phi = V_\phi I_\phi \cos\theta_\phi$$

$$P_{3\phi} = 3 P_\phi = 3 V_\phi I_\phi \cos\theta_\phi$$

$$= \sqrt{3} V_L I_L \cos\theta_\phi$$

* Reactive Power (Q)

$$Q_{AB} = Q_{BC} = Q_{CA} = Q_\phi = V_\phi I_\phi \sin\theta_\phi$$

$$Q_{3\phi} = 3 V_\phi I_\phi \sin\theta_\phi = \sqrt{3}\, V_L I_L \sin\theta_\phi$$

ملحوظة كل Power المعطاة في أسئلة
تكون (Power) لـ (3 Phase) يعني
هنقسمها على (3).

* Apparent Power (S)

$$S_\phi = P_\phi \pm J Q_\phi$$

$$S_{3\phi} = P_{3\phi} + J Q_{3\phi}$$

إثبات

* Instantinous Power

$$P_A(t) = V_{AN}(t) * I_{aA}(t) = V_m \cos(\omega t) \cdot I_m \cos(\omega t - \theta_\phi)$$

$$P_B(t) = V_m I_m \cos(\omega t - 120) \cos(\omega t - 120 - \theta_\phi)$$

$$P_C(t) = V_m I_m \cos(\omega t + 120) \cos(\omega t + 120 - \theta_\phi)$$

$$P_{3\phi}(t) = P_A + P_B + P_C = 1.5\, V_m I_m \cos(\theta_\phi)$$

→ time invarient

torque ← $\boxed{T = \frac{P}{\omega}}$ → time invarient

$$= 3\left(\frac{V_m}{\sqrt{2}}\right)\left(\frac{I_m}{\sqrt{2}}\right)\cos\theta_\phi = 3 V_\phi I_\phi \cos\theta_\phi$$

$$P_{3\phi} = \sqrt{3}\, V_L I_L \cos\theta_\phi$$

Ch : 4

Mutual inductance

ch: 4

Mutual inductance

أي ملف يمر به تيار ينشأ عنه فيض ϕ. (اتجاهه يتم بقاعدة اليد اليمنى)

$$V = \frac{d\lambda}{dt} \qquad \lambda \rightarrow \text{flux linkage}$$

$$\lambda = N\phi$$

$$\phi = \rho N i \qquad \rho \rightarrow \text{permeance}$$

سماحية أي وسط للمجال فيه لشغل خطوط الفيض المغناطيسي $\rightarrow \rho$

ρ

- Magnetic materials: $\rho \propto \phi$
- nonmagnetic: $\rho \rightarrow$ Constant $(\phi \propto i)$

$$V = \frac{d\lambda}{dt} = \frac{d}{dt}\left(N^2 \rho i\right) = N^2 \rho \frac{di}{dt}$$

$$V = L\frac{di}{dt} \qquad L \rightarrow \text{self inductance}$$

$$\boxed{L = N^2 \rho}$$

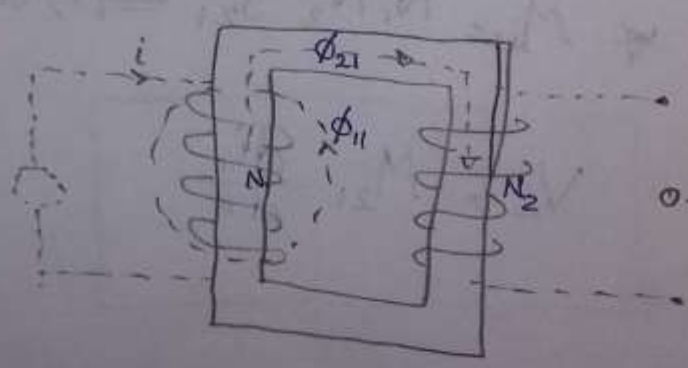
Mutual inductance (M)

هي الـ Parameter اللي يربط الجهد المستحث على أحد الملفين بالتيار المار بالملف الآخر.

$$\phi_1 = \phi_{11} + \phi_{21} = N_1 \rho_1 i_1$$

$$\phi_{11} = \rho_{11} N_1 i_1$$

$$\phi_{21} = \rho_{21} N_1 i_1$$



$$V_1 = \cancel{d}\frac{d\lambda_1}{dt}$$

$$\lambda_1 = N_1\phi_1 = N_1(\phi_{11} + \phi_{21})$$

$$\lambda_1 = N_1(\rho_{11}N_1 i_1 + \rho_{21}N_1 i_1)$$

$$\lambda_1 = N_1^2 \rho_1 i_1$$

$$V_1 = N_1^2 \rho_1 \frac{di_1}{dt} \cancel{N_1^2} = L_1 \frac{di}{dt}$$

* الجهد المتولد على الملفات N_2 نتيجة مرور التيار فيها ⇐

$$V_2 = \frac{d\lambda_2}{dt} \cancel{= N_2\phi_{21}}$$

$$\lambda_2 = N_2\phi_{21}$$

$$\phi_{21} \cancel{\phi_{21}} = \rho_{21} N_1 i_1$$

$$\lambda_2 = N_1 N_2 \rho_{21} i_1$$

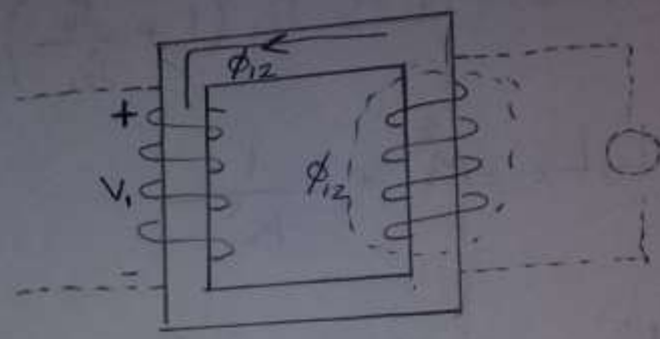
$$V_2 = \frac{d}{dt}(N_1 N_2 \rho_{21} i_1)$$

$$\boxed{V_2 = N_1 N_2 \rho_{21} \frac{di_1}{dt}}$$

* $M_{21} = N_1 N_2 \rho_{21} \Rightarrow$ Mutual Inductance (H)

$$\boxed{V_2 = M_{21}\frac{di_1}{dt}}$$

$$V_2 = N_2^2 \wp_2 \frac{di_2}{dt}$$



$$V_2 = L_2 \frac{di_2}{dt}$$

$$V_1 = N_1 N_2 \wp_{12} \frac{di_2}{dt}$$

$$V_1 = M_{12} \frac{di_2}{dt}$$

$$M_{21} = N_1 N_2 \wp_{21} \quad , \quad M_{12} = N_1 N_2 \wp_{12}$$

$$\because \wp_{21} = \wp_{12}$$

$$\boxed{\therefore M_{21} = M_{12} = M}$$

*relationship between L_1, L_2, M

$$L_1 = N_1^2 \wp_1^2 = N_1^2 (\wp_{11} + \wp_{21})$$

$$L_2 = N_2^2 \wp_2^2 = N_2^2 (\wp_{22} + \wp_{12})$$

$$L_1 L_2 = N_1^2 N_2^2 (\wp_{11} + \wp_{21})(\wp_{12} + \wp_{22})$$

$$L_1L_2 = N_1^2 N_2^2 \wp_{21}^2 \left(1+\frac{\wp_{11}}{\wp_{21}}\right)\left(1+\frac{\wp_{22}}{\wp_{21}}\right)$$

$$L_1L_2 = M^2 * \frac{1}{K^2}$$

$K \longrightarrow$ Mutually Coupling. $\boxed{0 \leq K \leq 1}$

$$M^2 = L_1 L_2 K^2$$

$$\boxed{M = K\sqrt{L_1L_2}}$$

[1] if $K = 0$

$\therefore M = 0$ لا يوجد وصل بين الملفين

[2] if $K = 1$

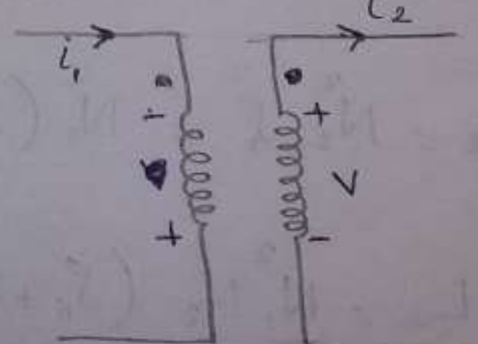
$M = \sqrt{L_1L_2}$ * أى أن كل الفيض القادم سيتحول إلى ϕ_{21}

ملحوظة

* أى ملفين يكون بينهم ربط (Coupling) ينشأ على كل منهم (Mutual voltage)

* يتم تحديد الـ (Polarity) لـ (Mutual voltage) بواسطة Dot marking.

* إذا كان التيار i_1 داخل لـ (Dot) بتاعة الملف فالـ (Polarity) تكون على الملف الآخر ($\pm$) والعكس يحدث مع i_2.

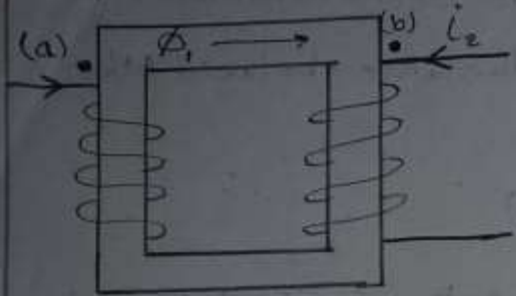


كيفية تحديد الـ (Polarity)

① نقوم بفرض تيار لأحدهما داخل الملف.

② نضع (Dot) عند هذا التيار (عند a)

③ نشاهد إتجاه الفيض بقاعدة اليد اليمنى.



(A) لو ϕ_1 ، ϕ_2 في نفس الإتجاه ← نقوم بوضع (Dot) عند مكان دخول التيار للملف الآخر.

(B) لو ϕ_1 ، ϕ_2 مش في نفس الإتجاه ← نضع (Dot) عند مكان خروج التيار للملف الآخر.

Sheet

sheet 4

[1] Two magnetically Coupled Coils have self-inductance of 52 mH and 13mH, respectively. The Mutual Inductance between the Coils is 19.5 mH

a) What is the Coefficient of Coupling?

b) For these two Coils, what is the largest value that M Can have. c) ~~The physical Construction of four pairs of magnetically coupled coils is show~~

d) Assume that the physical structure of these coupled coils is such that $\rho_1 = \rho_2$. what is the turn ratio $\frac{N_1}{N_2}$?

solution

$L_1 = 52mH$, $L_2 = 13mH$, $M = 19.5mH$

a) $$K = \frac{M}{\sqrt{L_1 L_2}} = \frac{19.5 \times 10^{-3}}{\sqrt{52 \times 13 \times 10^{-6}}} = \boxed{0.75}$$

b) at $K = 1$

$$M_{max} = \sqrt{L_1 L_2} = \boxed{26\ mH}$$

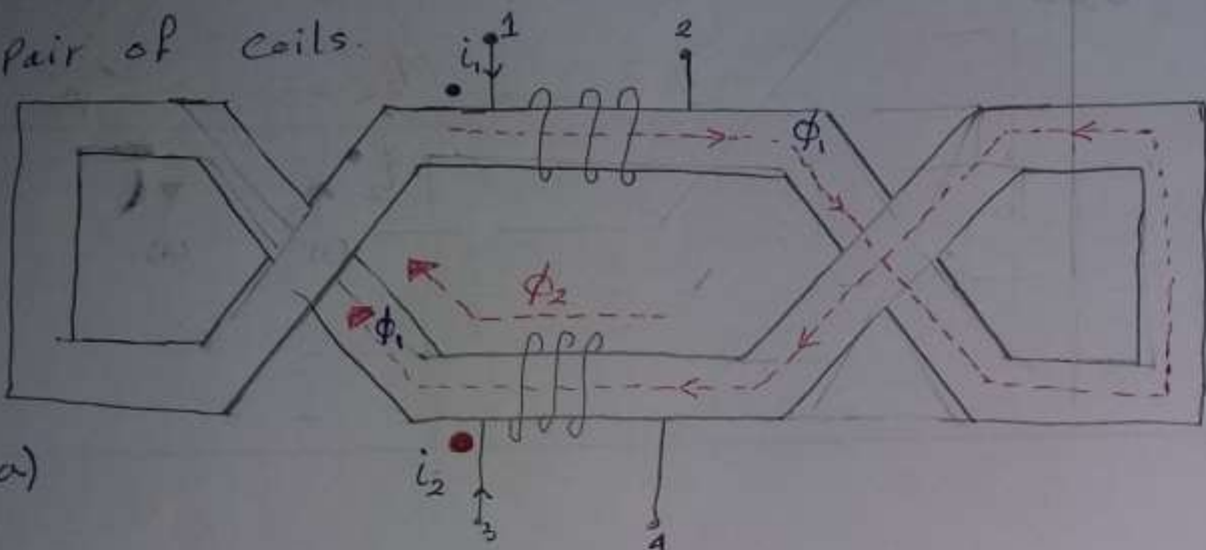
c) $\rho_1 = \rho_2$

$$L_1 = N_1^2 \rho_1^2 = 52 \quad , \quad L_2 = N_2^2 \rho_2^2 = 13$$

$$\frac{52}{13} = \frac{N_1^2}{N_2^2} = \frac{4}{1}$$

$$\boxed{\therefore \frac{N_1}{N_2} = \frac{2}{1}}$$

$\boxed{2}$ The physical construction of four pairs of magnetically coupled coils is shown in fig. 1. Assume the magnetic flux is confined to the core material in each structure. show the possible locations for the dot markings on each pair of coils.



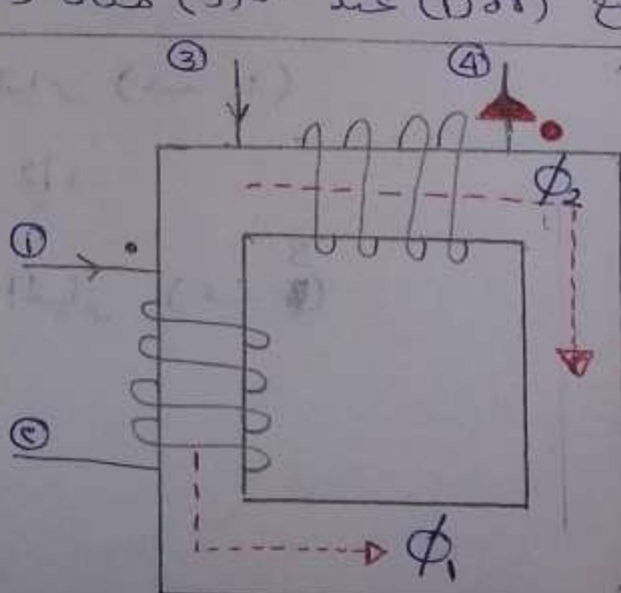
a)

① نضع (dot) عند مكان دخول التيار عند (1) .

② نلاحظ أن ϕ_1 , ϕ_2 في نفس الإتجاة .

③ نضع (Dot) عند (3) مكان دخول التيار.

b)

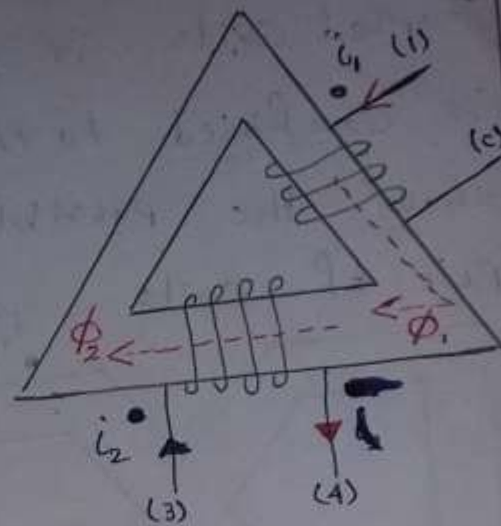


ⓐ نفرض أن (Dot) عند مكان دخول التيار,

ⓑ ϕ_1 , ϕ_2 في إتجاهين متضادين.

ⓒ نضع ال (Dot) عند مكان خروج التيار عند (4) .

c

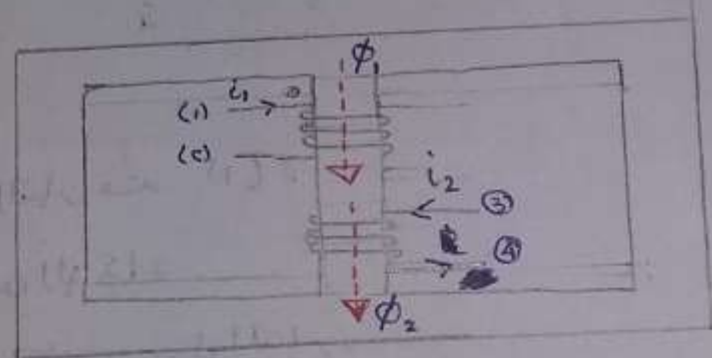


a) نضع (Dot) عند مكان دخول التيار عند (1)

b) نلاحظ أن ϕ_1 ، ϕ_2 في نفس الاتجاه.

c) نضع (Dot) عند مكان دخول التيار عند (3).

d



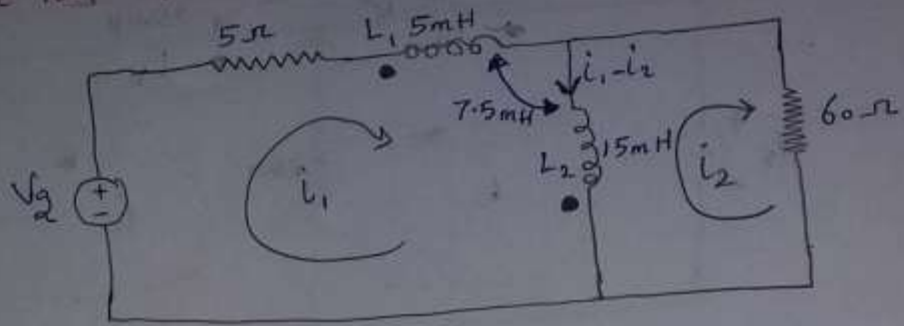
a) نضع (Dot) عند مكان دخول التيار (عند 1)

b) نلاحظ أن ϕ_1 ، ϕ_2 في نفس الاتجاه.

c) نضع (Dot) عند مكان دخول التيار (عند 3)

* Write down the loop equations for the following circuits

a)



* نفرض أن i_1 أكبر من i_2 فيكون التيار (i_1-i_2) خارج من (Dot) فتكون الـ (Polarity) على L_1 (- +) $\frac{M\, d(i_1-i_2)}{dt}$

* لو $i_2 > i_1$ ← التيارات اتجاههم داخل لـ (Dot) يعني (Polarity) على L_1 (+ -) $-\frac{M\, d(i_1-i_2)}{dt}$ ولكنها ثابتة .

Equations

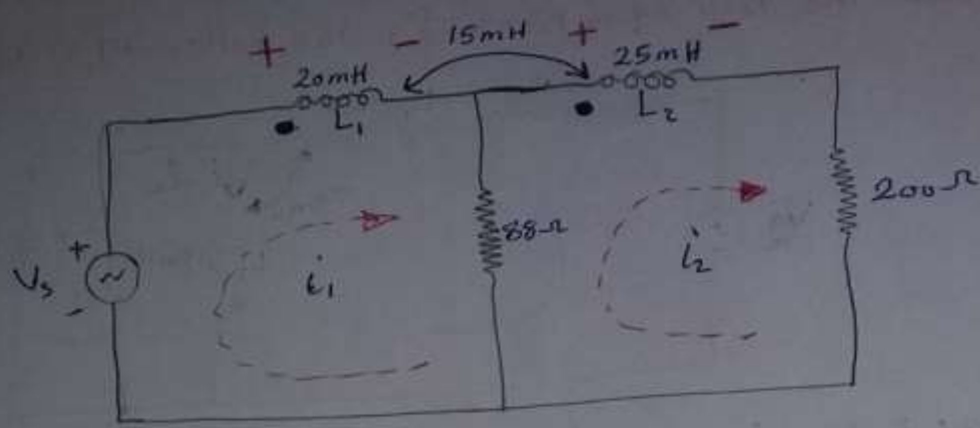
For Loop ①

$$V_g - 5 i_1 - L_1 \frac{di}{dt} - M \frac{d(i_1 - i_2)}{dt} - L_2 \frac{d(i_1 - i_2)}{dt} + M \frac{di_1}{dt} = 0$$

For loop ②

$$-L_2 \frac{d(i_2 - i_1)}{dt} - M \frac{di_1}{dt} - 50 i_2 = 0$$

b)



* التيار i_1 داخل لل (Dot) فتكون ال (Polarity) لـ L_2 (+ -)
و بالمثل مع L_1 (+ -)

Equations

~~Vs - L di~~

For Loop (1)

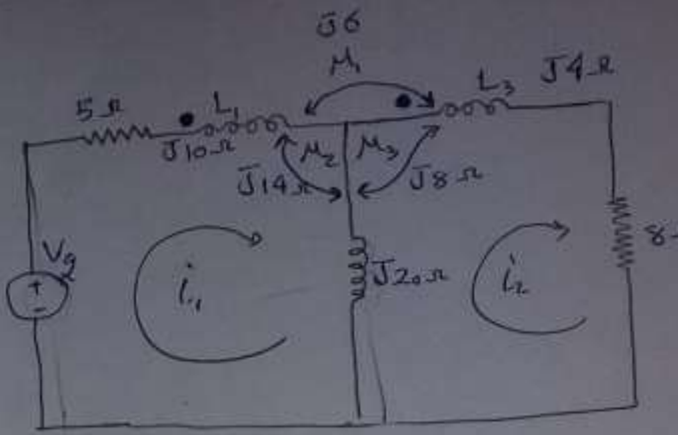
$$V_s - L_1 \frac{di_1}{dt} - M \frac{di_2}{dt} - 88(i_1 - i_2) = 0$$

For Loop (2)

$$-88(i_2 - i_1) - L_2 \frac{di_2}{dt} - M \frac{di_1}{dt} - 200 i_2 = 0$$

c)

ملحوظة لو أعطى ملفات لا يوجد عليها (Dot) ولا (<——>) فهو (self Inductance).



* i_1 ← داخل على (Dot) فينشأ على

$$L_2 \longrightarrow M_2 \frac{di_1}{dt} \quad , L_3 \longrightarrow M_3 \frac{di_1}{dt}$$

* $(i_1 - i_2)$ للملف i_2 بسبب

$$L_1 \longrightarrow M_2 \frac{d(i_1 - i_2)}{dt} \; (+ \;\; -) \qquad , L_3 \longrightarrow M_3 \frac{d(i_1 - i_2)}{dt} \; (+ \;\; -)$$

* i_2 ← داخل لـ Dot

$$L_1 \longrightarrow M_1 \frac{di_2}{dt} \quad , \quad L_2 \longrightarrow M_3 \frac{di_2}{dt}$$

For Loop (1)

$$V_g - 5i_1 - L_1 \frac{di_1}{dt} - M_1 \frac{di_2}{dt} - M_2 \frac{d(i_1 - i_2)}{dt} - L_2 \frac{d(i_1 - i_2)}{dt}$$

$$- M_3 \frac{di_2}{dt} - M_2 \frac{di_1}{dt} = 0$$

For Loop (2)

$$- L_2 \frac{d(i_2 - i_1)}{dt} + M_2 \frac{di_1}{dt} + M_3 \frac{di_2}{dt} - L_3 \frac{di_2}{dt}$$

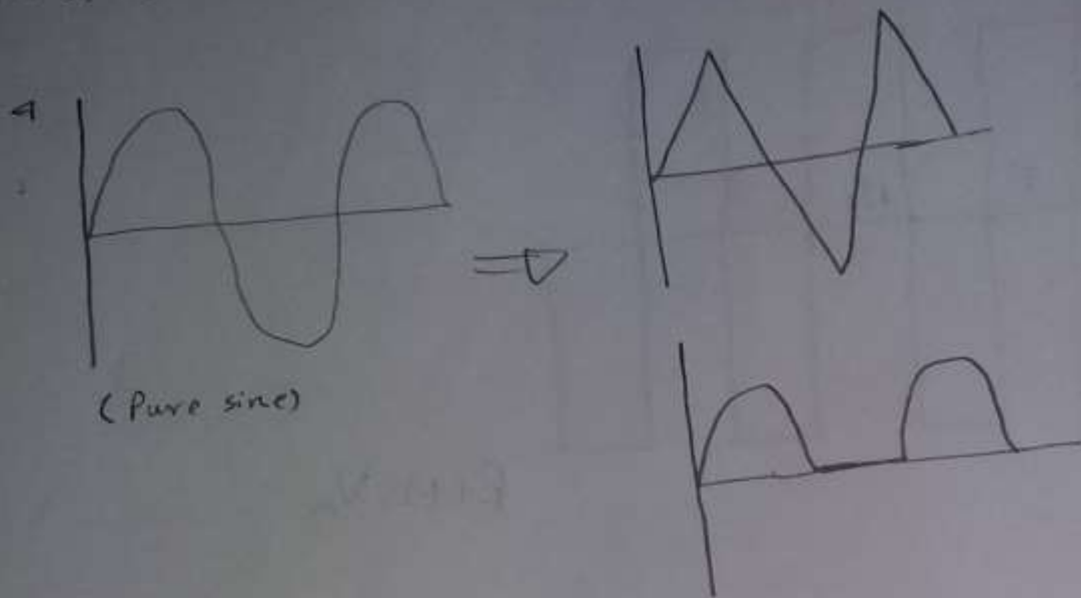
$$- M_1 \frac{di_1}{dt} - M_3 \frac{d(i_1 - i_2)}{dt} - 8 i_2 = 0$$

Ch:5

Fourier

Ch: 5   Fourier series

* أي مصدر (AC) يقوم بإخراج اشارة (Pure sine) ولكن بسبب وجود شوائب تؤثر على الموجه.



(Pure sine)

سوف ندرس هنا نوعان (Non sinusoidal and Periodic)

Cosisi. هاتين * الموجتين ممكن ان يتم تفكيكهم الى مجموعة sine, cosine

$$f(t) = a_v + \sum_{n=1}^{\infty} a_n \cos(n\omega_0 t) + b_n \sin(n\omega_0 t)$$

angular frequency

~~$\omega_0 \rightarrow$ frequency of~~ $a_v, a_n, b_n \rightarrow$ Fourier harmonic Coeffeicients.

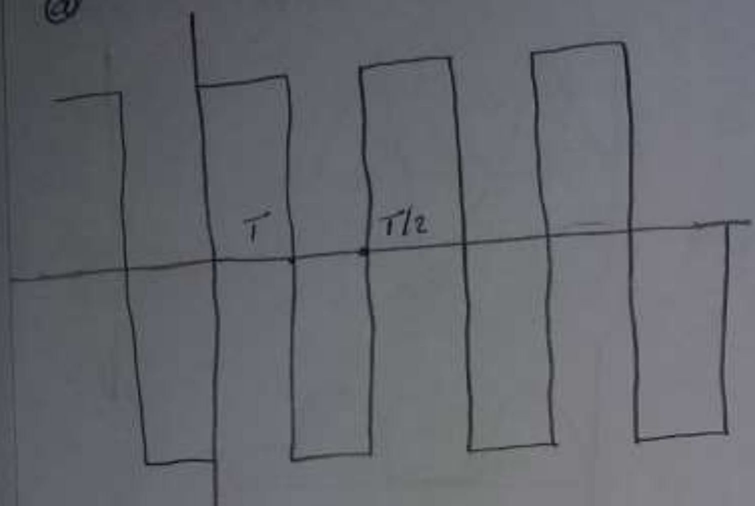
~~$2\omega_0 \rightarrow$ frequency of~~

$$a_v = \frac{1}{T}\int_{t_0}^{t_0+T} f(t)\,dt \quad , \quad b_n = \frac{2}{T}\int_{t_0}^{t_0+T} f(t)\sin(n\omega_0 t)\,dt$$

$$a_n = \frac{2}{T}\int_{t_0}^{t_0+T} f(t)\cos(n\omega_0 t)\,dt$$

1

(a)



$f(t) = V_m$

$\therefore$

$a_v = 0 \quad , a_n = 0$

تكامل على نصف الفترة

$$b_n = \frac{4}{T} \int_0^{T/2} f(t) \sin(n \omega_o t)\, dt$$

$$= \frac{4}{T} \int_0^{T/2} V_m \sin(n \omega_o t)\, dt$$

$$\omega_o = \frac{2\pi}{T}$$

$$= \frac{4 V_m}{T} \left. \frac{-\cos(n \omega_o t)}{n \omega_o} \right|_0^{T/2}$$

$$= \frac{4 V_m}{n T \frac{2\pi}{T}} \left[-\cos\left(n \frac{2\pi}{T} * \frac{T}{2}\right) + 1 \right]$$

$$\boxed{b_n = \frac{4 V_m}{n \pi}}$$

$$f(t) = \sum_{n=1}^{\infty} b_n \sin n w_0 t$$

$$= \sum_{n=1}^{\infty} \frac{4V_m}{n\pi} \sin(n w_0 t)$$

$$= \frac{4V_m}{\pi} \sin w_0 t + \frac{4V_m}{3\pi} \sin 3 w_0 t + \cdots$$

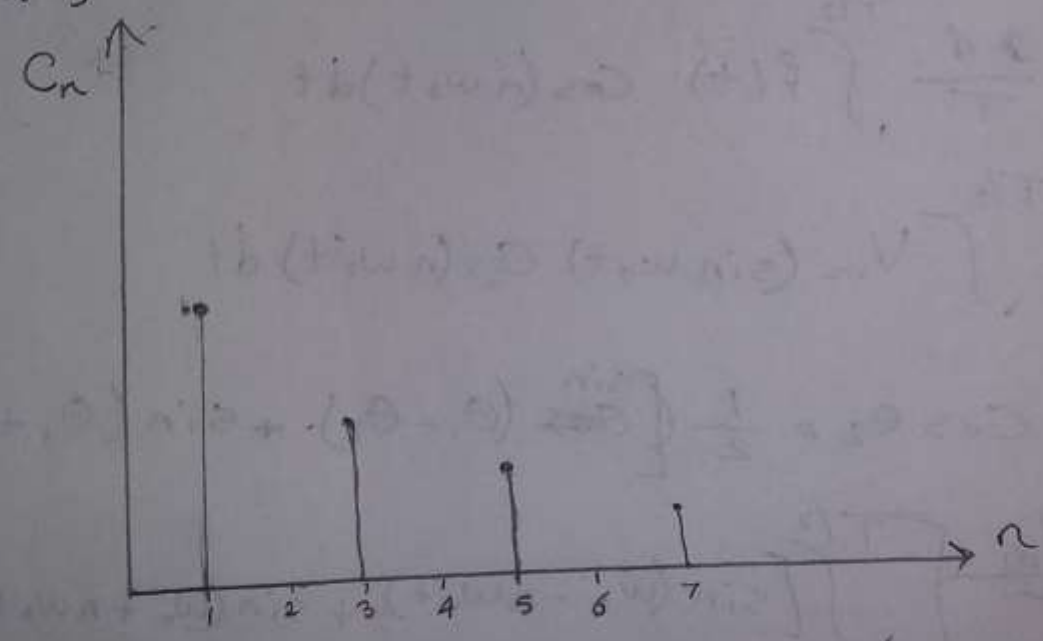
→ spectrum

$$C_n = \sqrt{a_n^2 + b_n^2} \quad , C_0 = a_v$$

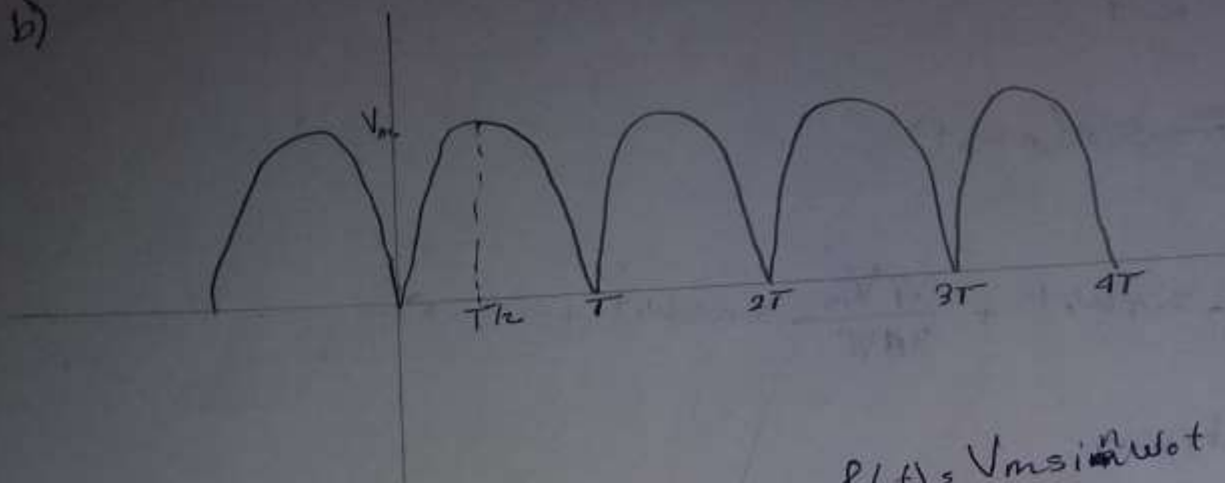
$$C_1 = \sqrt{a_1^2 + b_1^2} = \frac{4V_m}{\pi}$$

$$C_2 = \sqrt{a_2^2 + b_2^2} = 0$$

$$C_3 = \sqrt{a_3^2 + b_3^2} = \frac{4V_m}{3\pi}$$



b)



$f(t) = V_m \sin \omega_0 t$

even function

$a_v \checkmark$, $a_n \checkmark$, $\boxed{b_n = 0}$

$$a_v = \frac{2}{T}\int_0^{T/2} f(t)\,dt = \frac{2}{T}\int_0^{T} V_m \sin(\omega_0 t)\,dt$$

$$= \frac{2V_m}{T}\left. -\frac{\cos(\omega_0 t)}{\omega_0}\right|_0^{T/2} = \frac{2V_m}{T}$$

$$a_n = \frac{4}{T}\int_0^{T/2} f(t)\cos(n\omega_0 t)\,dt$$

$$= \frac{4}{T}\int_0^{T/2} V_m(\sin\omega_0 t)\cos(n\omega_0 t)\,dt$$

$$\sin\theta_1\cos\theta_2 = \frac{1}{2}\left[\sin(\theta_1-\theta_2)+\sin(\theta_1+\theta_2)\right]$$

$$= \frac{2V_m}{T}\left[\int_0^{T/2}\left[\sin(\omega_0 - n\omega_0 t) + \sin(\omega_0 + n\omega_0 t)\right]dt\right]$$

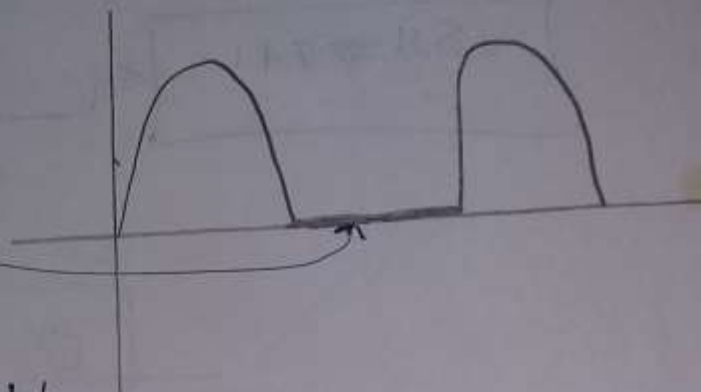
$$= \frac{2V_m}{T}\left[\frac{-\cos(\omega_0 - n\omega_0 t)}{\omega_0(1-n)} - \frac{\cos(\omega_0 + n\omega_0 t)}{\omega_0(1+n}\right]_0^{T/2}$$

$$= \frac{2V_m}{T * \frac{2\pi}{T}} \left[\frac{-\cos(1-n)\frac{2\pi}{T}\frac{T}{2}}{1-n} - \frac{\cos(1+n)\frac{2\pi}{T}\frac{T}{2}}{1+n} + \frac{1}{1-n} + \frac{1}{1+n} \right]$$

$$= \frac{4V_m/\pi}{1-4n^2}$$

$\boxed{3}$

$$a_v = \frac{1}{T}\int_0^{T/2} V_m \sin nw_o t \, dt + 0$$



$$a_n = \frac{1}{T}\int_0^{T/2} V_m \sin w_o t \cos(nw_o t)\, dt + 0$$

$$b_n = \frac{1}{T}\int_0^{T/2} [V_m \sin w_o t \sin(nw_o t) dt + 0$$

Ch:6

Operational amplifier

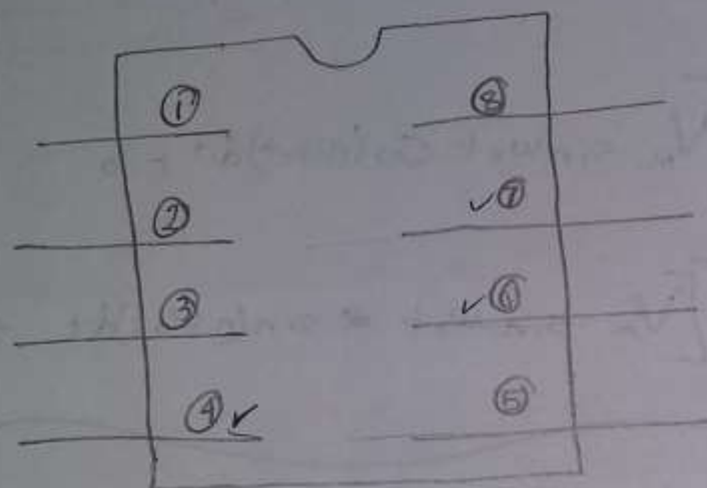
Ch. 6 — Operational amplifier

* عبارة عن دوائر متكاملة تستخدم في عمليات معينة مثل الجمع والطرح ....

* from analogue computer

دوائر متكاملة دوائر بها مقاومات وملفات ومكثفات مرتبطة مع بعضها تستخدم في عمليات.

* يكون طرفات "٤" أو "٦" أو "٨" ⟵ 741 ⇐ الكود



(2) → inverting input

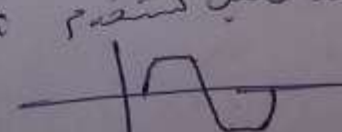
(3) → non inverting input

(4) $\xrightarrow{\text{يوصل ب}}$ -ve supply

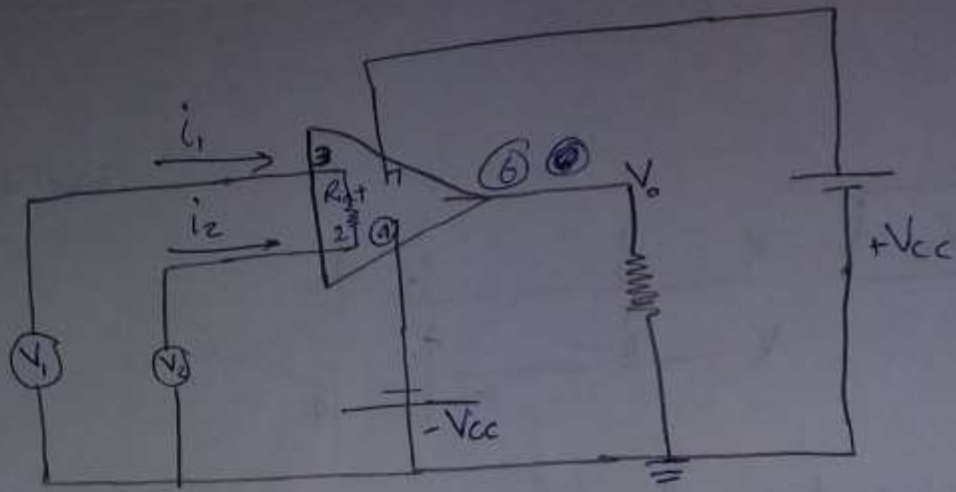
(7) $\xrightarrow{\text{يوصل ب}}$ +ve supply

(8) not connected

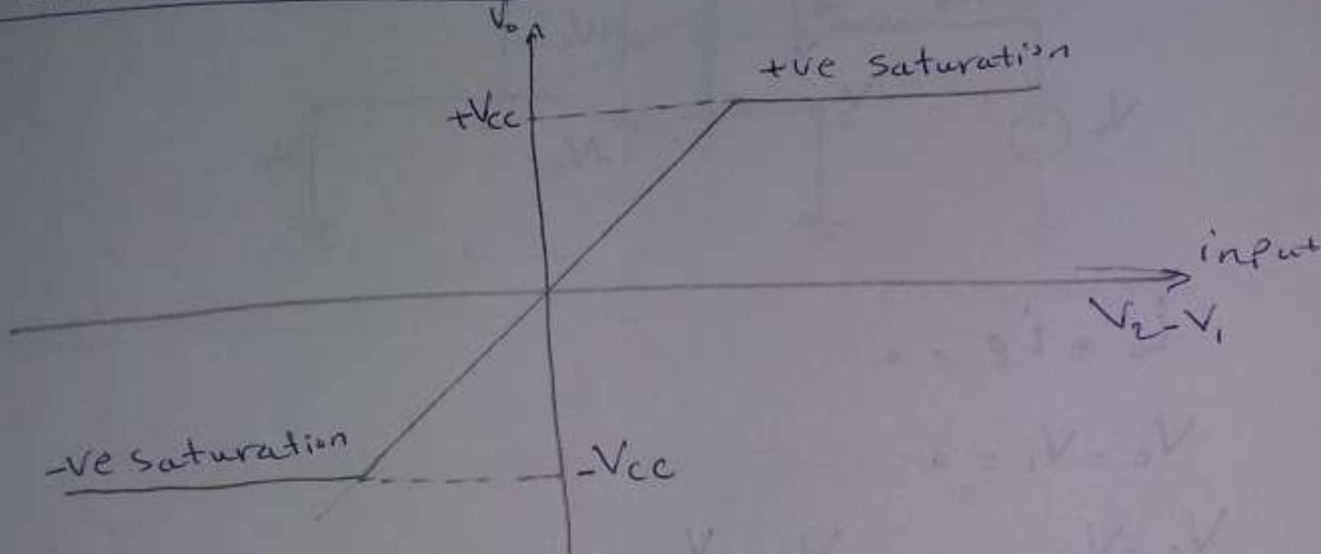
(1), (5) → null offset → لو عندي موجة مش عايزها تزيد عن حد معين نستخدم offset



(6) out put



* chls of amp.



$$V_o = A(V_2 - V_1)$$

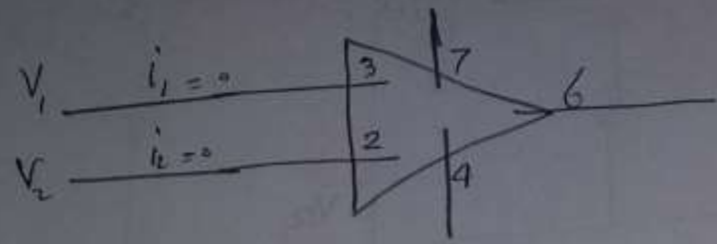
$A \longrightarrow$ gain

at ideal $\Longrightarrow A_v \longrightarrow$ very large $\simeq \infty$

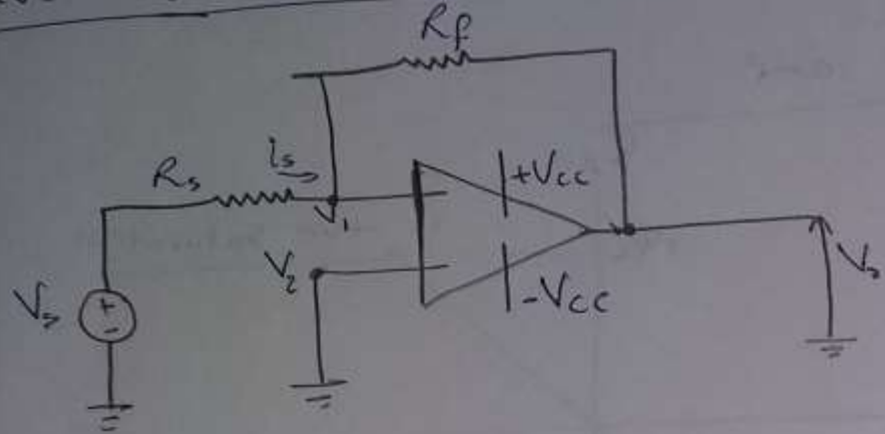
$$\therefore \frac{V_2 - V_1}{1} = \frac{V_o}{A\uparrow} \qquad \therefore V_2 - V_1 \simeq 0$$

$$\therefore \boxed{V_2 = V_1}$$

$\boxed{V_1 = V_2}$



1 Inverting Amplifier



$$i_s + i_f = 0$$

$$V_2 = V_1 = 0$$

$$\frac{V_s - V_1}{R_s} + \frac{V_o - V_1}{R_f} = 0$$

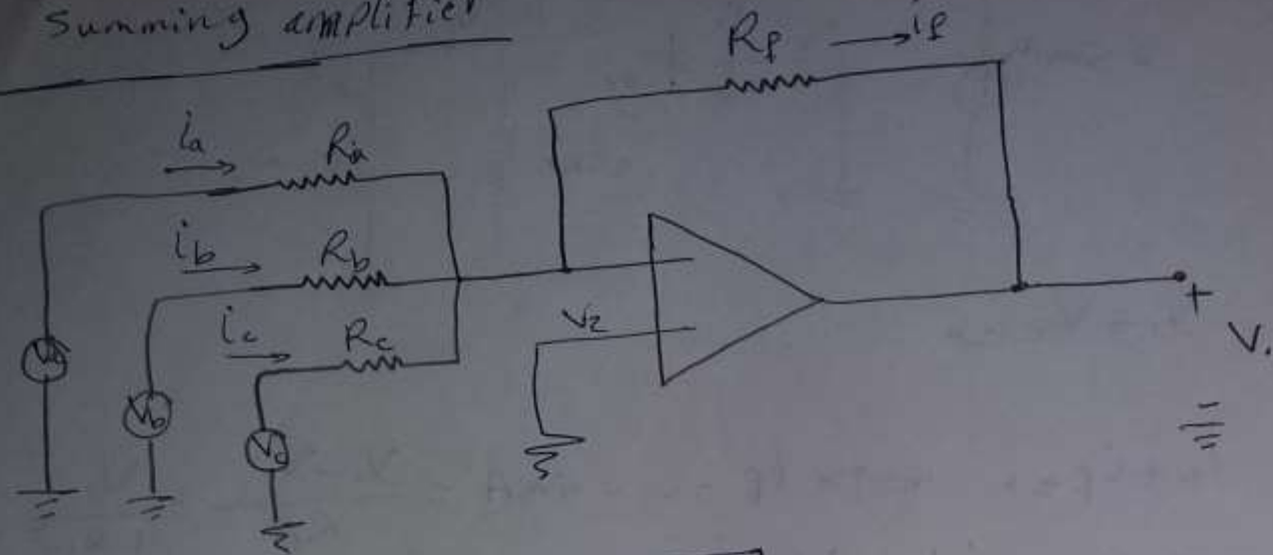
$$\frac{V_s}{R_s} = \frac{-V_o}{R_f}$$

$$\boxed{V_o = -\frac{R_f}{R_s} V_s}$$

inverted

[2]

Summing amplifier



$$\boxed{i_f + i_a + i_b + i_c = 0}$$

$$V_1 = V_2 = 0$$

$$\frac{V_o}{R_f} + \frac{V_a}{R_a} + \frac{V_b}{R_b} + \frac{V_c}{R_c} = 0$$

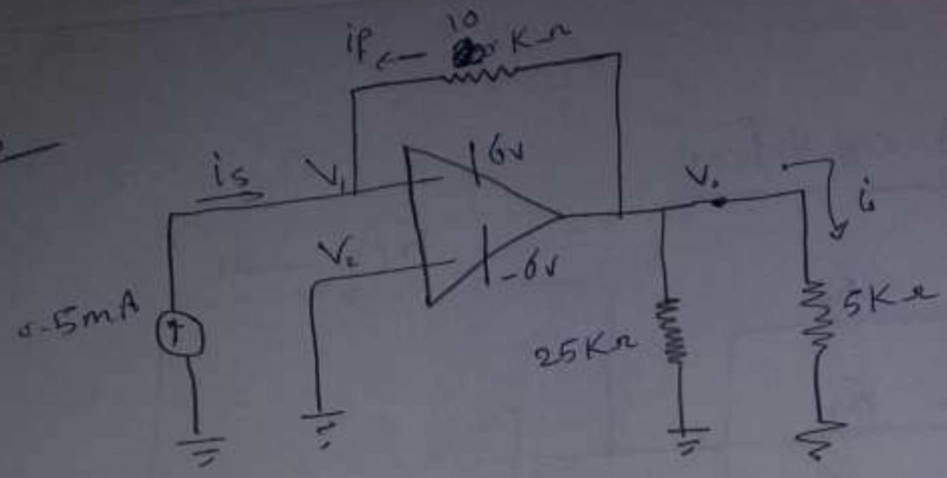
$$V_o = \left(\frac{-V_a}{R_a} - \frac{V_b}{R_b} - \frac{V_c}{R_c}\right) R_f$$

$$V_o = -\left(\frac{R_f}{R_a} V_a + \frac{R_f}{R_b} V_b + \frac{R_f}{R_c} V_c\right)$$

if $R_a = R_b = R_c = R_f$

$$\boxed{V_o = -(V_a + V_b + V_c)}$$

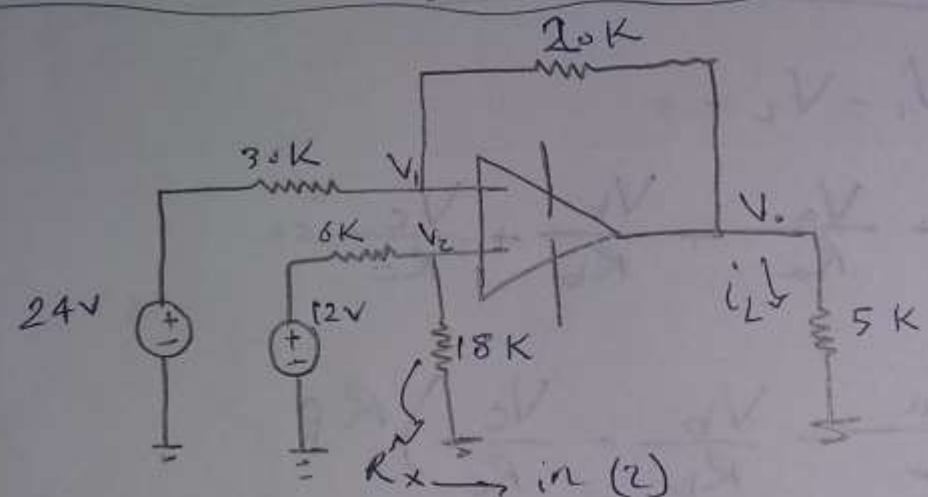
Find i_o



$V_1 = V_2 = 0$

$i_s + i_f = 0 \Rightarrow i_f = -0.5mA = \frac{V_o - V_1}{R_f} = \frac{V_o}{10*10^3}$

$V_o = -5V \longrightarrow i_o = \frac{V_o}{5} = 1$



$V_1 = V_2 = 12 * \frac{18}{18+6} = 9V$

$i_s + i_f = 0$

$\frac{24-9}{30*10^3} + \frac{V_o - 9}{20*10^3} = 0$

$V_o = -1V$ $\qquad i_L = \frac{V_o}{5*10^3} = J$

(c)
* find value of R_x so that (op. amp) not saturated

$$\frac{24-V_1}{30*10^3}+\frac{V_o-V_1}{20*10^3}=0$$

$$\frac{24}{30}-\frac{V_1}{30}+\frac{V_o}{20}-\frac{V_1}{20}=0$$

$$\boxed{V_1\left(\frac{1}{30}+\frac{1}{20}\right)=\frac{24}{30}+\frac{V_o}{20}}$$

$$V_o=5v \Rightarrow V_1=\frac{\frac{24}{35}-\frac{1}{4}}{\frac{1}{35}+\frac{1}{20}}=12\frac{R_x}{R_x+6*10^3}$$

$V_o=5v \rightarrow V_1=$ ~

$\therefore$ ~ $< R_x <$ ~